

Management Manual for

**Productive
R&D
Strategic and
Project Planning
and Budgeting**

September 1994

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ICIPE

**FINANCIAL AND ADMINISTRATIVE MANAGEMENT OF RESEARCH PROJECTS
IN EASTERN AND SOUTHERN AFRICA (FAMESA)**

A research and development (R&D) management training network of national R&D institutes, management and development training institutes, and councils of science and technology in Eastern and Southern Africa, based at the International Centre of Insect Physiology and Ecology, (ICIPE), P.O. Box 30772, Nairobi, Kenya

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FOREWORD

When a handful of scientists and administrators from research and development institutes (RDIs) first met at the International Centre of Insect Physiology and Ecology (ICIPE) in Nairobi in January 1982 to review steps towards undertaking effective reforms in the management of RDIs in the region, they discovered that little advance had been made over the last decade or so beyond the series of forums at which the subject had been discussed earlier. Their fears were, in fact, an echo of those of the African Heads of State and Government, who had expressed in 1980, their concern through the **Lagos Plan of Action** for the Development of Africa, 1980–2000.

The foresight that impelled the convening of the aforementioned meeting was timely and prophetic, since hardly one year passed when Africa began to experience its worst economic woes in terms of food crisis, external debt burden, and the balance of payments. FAMESA became the brainchild of these participants with a strategic vision, whose focus and clarity of purpose for the future of R&D activities in the region became the foundation for the establishment of FAMESA. Subsequent planning workshops served to refine the thoughts and formulate these into workplans. Much of the credit and inspiration for this initiative goes to the International Development Research Centre (IDRC), Canada, who not only provided the funds for an infrastructural set-up but whose staff also participated actively in planning activities. The German Foundation for International Development (DSE) later joined the IDRC in a generous gesture of support for one of the workshops which provided a significant milestone in the FAMESA project.

FAMESA has tried to avoid being a monolithic organization. It has therefore adopted a networking structure. The network is made up of a cross-disciplinary mix of people, including R&D researchers, management specialists and social scientists all possessing the singular aim of the improvement of the management of R&D efforts in national development. This goal is based on the following maxims:

1. That successful national development within the region requires an indigenous capability to derive and adopt technologies for economic, social and political growth;
2. That effective R&D requires sound management of the R&D enterprise;
3. That upgrading R&D management capabilities in the region requires the development of indigenous management training establishments, such as the development of institutions and appropriate curricula for training of R&D managers; and
4. That for the foregoing paradigm to be established and sustained in the region, it needs a facilitating and catalytic body such as FAMESA, which would serve as a link in assisting the individual institutions establish a network to promote mutual benefit and self-help among themselves.

FAMESA, based at the ICIPE, itself an RDI, has since made significant gains. It has undertaken RDI needs assessment and formulated strategies for fulfilling the needs, with the cooperation of several national RDIs and international institutions such as the Foundation for International Training for Third World Countries (FIT).

This **Management Manual for Productive R&D** is the product of a well-researched and energetic effort of the national RDIs. Several R&D management specialists and researchers made invaluable inputs in the preparation of the **Manual**; and we are grateful for their efforts. We are also grateful to the Canadian International Development Agency (CIDA) for the sponsorship of the **Manual**, its preparation and production.

I very much hope that you will enjoy this **Manual** and adapt it to your own institution's use. We shall, however, be pleased if you would be able to send us your feedback.

Professor Thomas R. Odhiambo

Director

International Centre of Insect Physiology and Ecology (ICIPE)
Nairobi, Kenya

20th April 1985

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***MANAGEMENT MANUAL FOR PRODUCTIVE R&D:
R&D STRATEGIC AND PROJECT PLANNING AND BUDGETING***

INTRODUCTION

INTRODUCTION

Training Objectives

By the end of this section, the participants will be able to:

1. Explain the need for R&D management training.
 2. Outline the purpose and contents of the **Manual**.
 3. Describe the **Manual** format, and the variety of ways in which it may be used for training purposes.
 4. Adapt the **Manual** for their optimum mode of study and learning.
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INTRODUCTION

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All of this material can be covered in one session, if it has been studied on an individual basis prior to the session.

INTRODUCTION

1. Need for Management Training

Introduction

This **Manual** is based on solid research experience by FAMESA on the management of RDIs in Eastern and Southern Africa and other developing countries. It represents a unique training experience. Needless to say, this premier **Management Manual for Productive R&D** will be adapted and revised by users to make it most applicable within each national system. But hopefully, the basic design will prove sufficiently effective to justify the development and publication of companion volumes covering the full range of RDI management topics. Hopefully it will stimulate sufficient reaction to encourage international sponsors to join in this R&D management training venture.

Observations on R&D Management

Observations in research and development institutes (RDIs), and discussions with their managers during consultancies and training exercises led to three fundamental assumptions which had the greatest influence on this **Manual** approach to the subject of R&D management:

1. The greatest sense of need expressed by R&D managers is for strategic level planning and incremental budgeting designed to perpetuate the RDI as an organization, R&D projects which are already underway, and new projects which are particularly attractive for new funding.
2. Managers appear to place far less priority on providing R&D project leaders with the role, responsibilities and resources needed to plan, budget, monitor and control their own projects.
3. The greatest need for management training among RDI managers is, therefore, a basic understanding and overview of management as a process which can enhance R&D productivity throughout the R&D institute.

Many RDI managers graduate to management positions from the ranks of technical specialists in charge of R&D projects. On the face of it this would suggest that they are

particularly responsive to the needs of R&D project leaders—and in fairness, we must conclude that some are. However, deficiencies in management experience and training often preclude their effectiveness in responding to these needs.

Further, their increased exposure to pressures and demands from controlling boards and granting agencies of the government, can distract their attention from the technical productivity of individual R&D projects and the resources, assistance and support needed by technical staff. Instead, it causes them to focus too much on such issues as the growth of the RDI they manage, growth in the R&D portfolio, and influence and longevity in the science and technology infrastructure of the country.

These conditions exist not because of any deficiencies in desire for R&D to impact national development. Rather, they exist because of considerable misunderstanding about the role of organizations, management, and managers in any enterprise—but particularly in the R&D enterprise. Therefore, this **Manual** presents management technology as a tool for R&D “productivity”. It focuses on the desired results of R&D projects and programmes. It emphasizes the role of R&D in creating and distributing new technologies for national development.

Secondly, while this first **Manual** details management techniques in planning and budgeting, it (and all future ones) will do so in a more general context of management as a collection of tools for improving R&D productivity. Therefore, for example, each **Manual** will start with an overview of R&D management; and will relate its particular skill emphases to the whole management process.

Pedagogical Considerations

Part of the uniqueness of this R&D management training venture lies in the pedagogical standards adopted for each **Manual**. They derive from experiences in designing, writing and delivering long-, and short-term training to R&D managers in developing economies—as well as familiarity with training materials developed by others in this business. Five particular standards have been applied to the development of this **Manual**:

1. **Mediated and Self-Instructional:** The **Manual** must be amenable to stand-up delivery by skilled trainers. But, it must also be amenable to self-instruction.
2. **Experiential:** The **Manual** must provide motivation and opportunity for trainees to practice key management technologies by solving realistic training problems and exercises.
3. **Visual:** The **Manual** must provide visual stimuli for both mediated and self-instructional modes of delivery.
4. **Interactive:** The **Manual** must stimulate, structure and process mutual problem solving discussions, not only between trainees and instructors, but among trainees themselves.
5. **Empirical:** The ideas and concepts introduced by the **Manual** must be selected on the basis of real observations about management practices and problems in Third World RDIs. Further, they must be presented in the same terms.

The first criterion, **mediated and self-instructional**, derives from the feeling that needs for training in R&D management are widespread. Therefore, it is wasteful to develop materials which are only meaningful and available to a few R&D managers, fortunate enough to be selected for a workshop.

Further, few materials developed for past courses and workshops are practical for review purposes by workshop participants—much less practical for participants to share with colleagues who could not participate in the training. We desire to overcome these limitations with the **Management Manuals for Productive R&D**.

The fourth criterion, **interactive**, stems from a sense that RDI participants fail to see the value of sharing their management problems and jointly seeking solutions to them—either between RDIs within countries, or between countries. Of course, there is the sectoral bias—that is, their feeling that a manager from an RDI in one sector (like agriculture) has nothing to offer a manager from an RDI in another sector (like industry). There is also a socio-cultural bias which inhibits managers of one culture from sharing with, and learning from, managers from another.

It is therefore, important for the **Manual** to demonstrate that all trainees have a great deal to offer each other. It must, therefore, stimulate them to share and solve their management problems together. One of the greatest long-range impacts of this **Manual**, and its companions, would be the generation of a worldwide network of R&D managers who actively seek each others' ideas and solutions to management problems.

The fifth pedagogical criterion, **empirical**, stems from the feeling that attempts to transfer management technology from business schools, or RDIs, in industrialized countries, to RDI managers in developing countries is ineffectual—if not inappropriate, unfair and insensitive. Many management techniques developed in Europe or the United States simply do not apply in that context. Therefore, the **Manuals** must present management in the context of real RDI problems and opportunities.

We have adopted two strategies for accomplishing this. On the one hand, the **Manual** requires participants to apply the concepts to their own RDI problems. All participants in training with these **Manuals** are encouraged to bring for these purposes:

1. Their country's current development plan.
2. Current statements of their country's science and technology policies.
3. The mandate statement for the institution they represent.
4. The current organization chart for their own institution.
5. Examples, from their own institution, of R&D proposals, budgets and final reports.

Many of the exercises in the **Manual** call for the participants to apply management principles to their own R&D institutions. These documents will greatly enhance the value of these exercises and the transfer of sound R&D management principles to real R&D settings.

The second approach to the requirement that R&D management training be based on the real needs, priorities and pressures experienced by R&D institutions in the Third World is fulfilled through the process used to develop the **Manual**. R&D management curriculum specialists visited a variety of such institutions in many countries prior to outlining the parameters of this **Manual**. Further, they integrated their observations in the body of the text so that trainees can see how the management concepts relate to real experiences. Finally, the whole **Manual** was critically reviewed and evaluated by a team of 15 R&D and management specialists from 10 Third World countries. Their work led to a major revision of the core curriculum.

Partners in R&D Management Training

If these strategies are successful, we expect demand to increase for RDI management training provided by instructors who are trained to use these **Manuals**. Further, we expect demand for use of them in the self-instructional format. It is likely, that RDIs will also organize their own training programmes, using the **Manual** as a basis for instruction. In other words, the opportunity exists, through a mechanism like this, for the R&D managers of the world to become partners in an effort to make dramatic improvements in the conduct, and ultimately, impact, of R&D on national development.

2. Purposes of the Manual

This **Manual** focuses on management concepts and practices which will improve the planning and budgeting of R&D projects and institutes. It is targeted on R&D managers at both the strategic and operational levels of the RDI.

Therefore it will be helpful to a wide variety of R&D managers. In fact, we would encourage its use in workshops comprised of participants from diverse, (1) sectors of the economy, (2) levels of technical sophistication, (3) management experience, (4) career status, and (5) R&D roles and responsibilities.

The **Manual** is designed to help R&D managers

1. Understand the vital role of R&D in national development;
2. Comprehend the special character of management in R&D projects and programmes;
3. Develop optimal organizational structures and styles of management for productive R&D work;
4. Perform R&D planning at both the institute and project levels;
5. Design budgets for R&D projects, divisions and institutes;
6. Recognize the role of the R&D proposal as the first attempt to pull together all critical elements of R&D planning; and,

7. Learn to apply plans and budgets to the process of ensuring that R&D work is productive, i.e., does have a desirable impact on economic development.

For these purposes, the Manual is divided into ten parts, as follows:

INTRODUCTION

Chapter I: National Development

Chapter II: R&D Management

Chapter III: Organizing

Chapter IV: Planning

Chapter V: Budgeting

Chapter VI: Proposing

Chapter VII: Monitoring and Control

GLOSSARY

GENERAL BIBLIOGRAPHY

Each Chapter is headed by a content outline and learning objectives. They will be useful for instructors who are planning the agenda for a programme of instruction. This is a stand-alone, self-instructional package with an inherent motivated sequence which should both stimulate and control the pace and quality of learning. Further, it is designed for easy adaptation to mediated instruction in a workshop setting.

So much for an introduction to the purposes and approaches of this **Manual**. The last section of this Chapter is directed to the user of the **Manual**. It explains the design, format and application of this training material.

3. Instructions for Users

Introduction: Welcome to the **Management Manual for Productive R&D**. We hope that it will enhance your R&D management skills, and be a pleasant learning experience.

Individual and Group Learning: The **Manual** is designed for either individual or group learning. It is self-instructional for the R&D manager who is studying independently. But it is also amenable to group learning; for use in workshops and other training contexts. It may be used by a manager participating in a large workshop, and then re-used as that manager shares it with a colleague back in the office. It was designed to make the most learning possible in the greatest variety of formats.

Exercises: Each Chapter contains exercises which help the R&D manager practice the ideas and concepts being discussed. These exercises may be conducted in a variety of

ways: individually in the self-instructional mode; overnight as homework during a mediated workshop; in teams during class time; or even in plenary. In most cases exercise answers are provided later so that the R&D manager may check their work.

Instructor(s) Notes: Occasionally there are notes to the Instructor(s), designed to help them plan and deliver a workshop, in the mediated mode. If the **Manual** is being used in the self-instructional mode, these may, and should, be ignored. Otherwise Instructor(s) may find them helpful in organizing the workshop.

Chapter Guides: Each section is headed by three pages. These give information which will help you plan your study. The first one is simply a title page. The second, however, presents the learning objectives for all the information contained in the Chapter.

It will give you an idea of what you should be able to do after you have learned all that is in the Chapter.

The third page is a Table of Contents for the Chapter. It is like any other Table of Contents, except that it includes notice of a **Session Break** wherever we think it would be helpful to divide the material into successive days of workshop sessions. It also shows the index numbers assigned to principal paragraphs in each Chapter. These numbers are designed to help you direct your study and discussion with other fellow-students.

Length of Sessions: A workshop planned for a group of R&D managers should include about 10 days of instruction. Some of the **Manual** Chapters comprise one-day sessions. Others are two or three-day sessions, depending on the pace set by participants and instructor(s).

Basically, we encourage half-day sessions during which new material is introduced. It usually works best to introduce new material in the morning. Then the afternoon is a good time for group exercises and field trips. This takes advantage of the participants' natural tendencies to be more alert and rested in the morning. Regardless, we encourage such workshops to include many frequent and diverse field trips and visits to RDIs so that learning includes as much experience and novelty as possible.

Also, instructor(s) should mix as many methods of instruction and exercise as possible; in order to maintain the interest of participants. Each of the exercises in the **Manual** may be adapted to a variety of techniques. It is up to the instructor(s) and participants to select those which are most useful, and instructional.

Above all, this learning experience should be enjoyable. It can be made so by adapting the **Manual** to the needs and learning habits of the R&D managers who look to it for guidance. The **Manual** was designed with flexibility in mind. We encourage R&D managers and instructor(s), alike, to adapt it to their own needs and interests.

Two-Column Format: If you thumbed through the **Manual**, you probably noticed that it is produced in a two column format. Furthermore, the typing font changed between columns. Here is why.

The left column provides the text for the programme of study. For an instructor it serves as the basis for lecture and discussion material.

For the R&D manager, it serves as the basic content for self-instruction or workshop preparation.

The right column, on the other hand, is where we relax a little bit and introduce some of the fun and flexibility in use of the **Manual**.

Your Notes: Here you can add your own thoughts, comments, questions and notes as you read, listen to a lecture or participate in a discussion. You are encouraged to write right on the page. That way your thoughts remain with the textual material; and the combination becomes a more powerful learning tool.

Our Notes: But you will also find our notes here. They take many forms. Some of them are questions which we would like to ask you to answer. They serve the purpose of providing a review of the textual material. If you can answer all these questions satisfactorily, then you probably have a good grasp of the material in the chapter.

These questions are also helpful to the instructor(s) who can use them as a basis for classroom discussion; they can even be used to develop small group, team, exercises.

Each question is located next to the textual paragraphs (in the left column) which provide a basis for answering them. So if you have difficulty with them, you will have no trouble finding out where to go for help.

"Cases": The right column also contains descriptions of real RDI experiences which characterize what we are talking about in the text. We call them "cases" because they represent real situations. However, we use the word advisedly because these are really too short and undeveloped to represent cases in the strictest sense of the word. They are included to add a flavor of reality to what we are discussing in the text.

Emphases: We also use the right column to emphasize key points. Sometimes we do it by making a comment. Other times we may do it with a simple diagram. But do pay attention; those notes in the right column—our notes and your notes—are like a traffic signal. They direct your travel through this course of instruction; and they regulate your learning.

Definitions: As with any new material, you will undoubtedly run into new words. Many of them are important for you to learn because they are part of the special language of R&D management. We try to emphasize them in a couple of ways.

The second topic of each Chapter in the **Manual** presents new definitions. But, we also print these words in boldface type the first time they appear in the text. That should draw your attention to them. Then, their definitions are usually underscored. Finally, we have included a GLOSSARY of over 85 words which will also help you adjust to the language.

Boldface Text: We also use the boldface text to emphasize one key idea throughout this **Manual**. If nothing else, we sincerely hope that all participants exit this course of instruction with renewed appreciation for the role of R&D in national development.

Above all else, we want all participants to re-orient all of their management ideas, and practices, to actually achieve useful R&D results—what we are calling “productive R&D.” Therefore, we use the boldface type to emphasize summary statements about productive R&D.

Citations: Occasionally the text will also bear a person’s name in parentheses. This is a bibliographical citation. It means that the idea immediately preceding the citation came from another author. You may discover the original source of the idea by looking for that author’s name in the annotated BIBLIOGRAPHY which appears at the end of the **Manual**.

The bibliography is comprehensive. It contains far more sources than were cited in the text. And most of them are briefly reviewed for you. This was done to provide you a wider orientation to the literature so that you may pursue any topics on which you would like more information.

However, you will also find citations at the end of each Chapter. These are the sources which had the most direct impact on the development of material contained in the respective Chapters. All citations in the **Manual** are made in a modified Turabian style. Modifications in the format were made to simplify interpretation and abbreviate space requirements.

If this particular format is unfamiliar to participants from various regions of the world, we encourage flexibility and diligence. It was not possible to select a format which is known by all possible audiences. Turabian was picked as a basic format because of its simplicity.

Summary: Good luck and do have fun! Together we are embarked on a noble venture, i.e., to enhance development for nations of the world through the carefully managed application of the principles of science and investigation. There is no more noble cause—and no more challenging approach to it.

*MANAGEMENT MANUAL FOR PRODUCTIVE R&D:
R&D STRATEGIC AND PROJECT PLANNING AND BUDGETING*

CHAPTER I

NATIONAL DEVELOPMENT

NATIONAL DEVELOPMENT

Training Objectives

By the end of this chapter, the participants will be able to:

1. Define national development.
 2. Explain national development planning.
 3. Define research and development.
 4. Explain the relationship between R&D and national development.
 5. Describe the role of RDIs in national development.
 6. Distinguish between mission-oriented and client centered RDIs.
 7. Explain the role of institute-client relationships in determining R&D productivity.
 8. Identify critical elements of productive R&D.
-

NATIONAL DEVELOPMENT

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All of this material can be covered in one session, if it has been studied on an individual basis prior to the session.

CHAPTER I

NATIONAL DEVELOPMENT

R&D produces new technologies. Technology enables major improvements in the productivity of human effort and the efficiency of use of the earth's resources. What could be more significant for a resource-poor or unproductive society? (Sharif)

1.11 Introduction: What is R&D? Why do countries with developing economies expend significant amounts of resources on R&D? Why should they spend more? What is the relationship between R&D, technology and national development? How do we know when R&D is productive?

How many R&D institutes are in your country?

List the technologies they represent:

1.12 At the outset, the country offers vital national resources (personnel, facilities, expensive equipment, real property, money) for some kind of activity known as "research and development" (R&D). Then, after that activity is completed, the country looks for significant improvements in vital sectors of the economy. What is this relationship between R&D and national development? Is it real; or is it mythical?

1.21 National Development: "National development" means different things to different people. Even economists do not always agree on it. But for the sake of this training programme, we must agree

What does "national development" mean to you? Write here, as many

on a definition. Traditionally, development is synonymous with economic growth as measured in monetised economies by factors like Gross Domestic Product (GDP) and Gross National Product (GNP). But lately, these interpretations of development have come under fire.

1.22 A more recent approach to development interprets it as the availability of all resources needed to provide a population with "basic human needs." Economic indicators which relate to this criterion include employment and income distribution. Many development planners add two other criteria to this interpretation of development:

- Popular participation and control of national development processes; and,
- Maintenance of a sound ecological environment

1.23 National development is the process that ensures the most equitable positive change in these factors, for all elements of society. In many developing countries, the largest elements of the population are also the least developed—suffering from multiple problems of poverty, illness, illiteracy, malnutrition, social inequality, and so on. Most of the poor live in rural areas and urban slums. National development must be directed toward the poor majority of the region.

1.31 **National Development Planning:** Governments of developing countries have goals policies and criteria for ensuring national development. They are usually embodied in national development plans. A **national development plan** is an aggregate of sectoral and often regional plans that specify government development strategies for a given period of time (usually four, five, or up to 10 years). Such strategies are further reduced in the same document into programmes which are budgeted over the same planning period.

1.32 However, due to changing economic circumstances, these programme budgets must be more frequently updated. Some countries use what they call a "forward budget" for this pur-

characteristics of national development, as you can think of:

What is meant by "popular" in this sentence?

How do you know when the environment is "sound"?

What is "equitable positive change"?

Examine your country's current national development plan.

Does it specify "goals" for national development?

Is it organized by "sectors" of development activity?

What is the period of time which it covers?

What kind of financial information does it contain?

How was it developed?

pose. It usually projects programme costs over a two- to three-year period. Finally many countries also project an annual budget for development activity. These annual budgets review the performance of the economy, propose measures for raising revenue and allocate expenditures in various forms over the financial year.

1.33 Annual budgets are often divided into "recurrent" and "development" budgets. Recurrent budgets detail expected costs for activities that are continued from the previous budgeting period. Development budgets project costs for new development initiatives.

1.34 Finally, annual and other budgets are, from time to time, updated by a variety of "sessional papers" which take into account internal and external forces that impact the economy. Obviously, a lot of serious thinking goes into planning for enhanced development of the nation.

1.41 **Research and Development:** The trend in recent years has tended to favour the theme that national development is no longer the exclusive realm of economists and planners. It has been found necessary to involve scientists as well.

1.42 For operational purposes, science may be viewed as the study of the nature of mankind and his environment. **Technology** then, is the body of knowledge which provides mankind the ability to manipulate nature to his advantage.

1.43 In the science and technology sector, research and development (R&D) is generally recognized as the most important tool. In this **Manual** R&D means:

An investigative and adaptive process using a wide range of methods for deriving and applying knowledge to enhance national development.

1.44 Thus, R&D should be understood as a catalyst for national development. In that role it often serves as a prerequisite to sound planning

Did your organization have a hand in developing it? Explain.

How often is it updated. Why?

How does it relate to the annual government programme planning process?

Does your government distinguish between "recurrent" and "development" budgets? Explain.

How does your country's development planning and budgeting process relate to what is explained here?

What is R&D?

How does it relate to your country's science and technology policy?

What is meant by "investigative" and "adaptive" in this definition?

What is meant by "deriving" and "applying"?

Why does this definition focus on "... to enhance national development"?

and policy evolution by providing new options to help revise old and accepted practices.

1.45 R&D can only act in this catalytic role if its objectives and operations are in line with national development plans, for which priorities have been extracted from national science and technology policies. Such R&D becomes “productive” when it provides solutions to key development problems.

1.51 **R&D Institutes:** The conduct of R&D requires specialty trained people, operating specialized equipment and processes, reading and writing special kinds of information, and drawing on resources which are allocated for these special purposes. The special nature of R&D argues for special facilities and organization—thereby creating entities known as **R&D institutes, or RDIs**.

1.52 The mission of an RDI originates with its mandate to apply R&D processes to the country’s development priorities. There remains considerable question, however, just how well the mission of any particular RDI is geared to the country’s national development goals. A study recently published by the United Nations (UNDP/ UNIDO) concluded that statements of the role of RDIs in relation to specific national development objectives, “...are in most cases either nonexistent or extremely vague.” (United Nations) Examples cited included these two:

- Contribute to industrial development.
- Contribute toward self-sufficiency.

1.53 This study highlights an essential quality of RDI management which is that RDI plans and programmes must parallel those government policies which relate to issues of national development.

1.54 In effect, an RDI is an operational instrument for achieving the development goals of government. Its mission is to fulfill those development goals which apply to its sector and resources. Its R&D priorities are the same as those stated in government development policies.

How does R&D relate to the country’s national development planning?

An RDI is an operational instrument for achieving the national development goals of the country!

What does that mean?

Do R&D people in your RDI recognize their role in national development?

Does government in your country recognize the RDI’s role in national development?

What are some indicators that government does recognize the RDI’s role in national development?

How can you tell when government is not sufficiently aware of the RDI’s potential contribution to national development?

1.55 As a consequence, if government development policies are vague and ambiguous, so too will be the programmes of RDIs.

1.61 **Mission-Oriented or Client-Centered:** Many R&D management specialists differentiate between **mission-oriented**, and client-centered RDIs. The former are those most often charged by government to fulfill grand development schemes through the application of R&D problem solving techniques. They, too, are almost wholly dependent on sponsoring government agencies for financial and other resources.

1.62 **Client-centered RDIs**, on the other hand, are those which more often engage in R&D in response to the stated needs and special requests of technology users, who pay for these services.

1.63 These, for example, would include industrial RDIs which accept contracts to develop special manufacturing techniques for a specific company in the manufacturing sector. Most often the "clients" for such technology operate in the profit-making business. Hence less altruism inherent in the description of the RDI.

1.64 We have considerable difficulty with this distinction because both types of RDI have a mission to engage in R&D activities which will enhance national development. We fail to see why all those RDIs which facilitate economic development in the private sector are considered less mission-oriented than those which operate more in the public domain.

1.65 But there is a more significant complaint about this distinction. The distinction is artificial; and, ultimately has had the effect of inhibiting the productivity of those RDIs which operate more along "mission-oriented" lines. This distinction ignores the vital role of the end-user of technology, or R&D clients, in the R&D process. End-users must be involved in R&D in both kinds of RDIs.

1.71 **Institute-Client Relations:** Mission-oriented RDIs usually obtain their mandate and mission from government bodies. Theoretically, at least, such government bodies prescribe RDI roles

Who are the clients for work done in your RDI?

What makes a "client"?

Do they have to pay for the R&D work, to be called a "client"?

What is the difference between mission-oriented, and client-centered RDIs?

What is the "mission" of the former; and who are the "clients" of the latter.

Do client-centered RDIs have no "mission"?

Do mission-oriented RDIs have no "clients"?

Why are client-centered RDIs generally more productive than mission-oriented RDIs?

on the basis of some understanding about the needs of society and economy in the country.

1.72 But the real difference between mission-oriented RDIs, and client-centered RDIs, is that the former are farther removed from the ultimate users of any technologies the RDI may derive. In contrast, the latter are consulted, contracted and committed by the ultimate users of their technologies.

1.73 The proximity of the institute-client relationship, for client-centered RDIs, generates far more productive R&D work; with far greater overall effectiveness and efficiency. The client who is paying for the R&D work will most likely have a very precise idea of the desired characteristics of the resultant R&D.

1.74 Further, they will probably insist on some role in monitoring the expenditure of their funds for R&D, and the project's technical progress. They may insist on a major role in the R&D process itself—in order to further ensure that they get just exactly what they want, and what they paid for.

1.75 Who, on the other hand, are the clients for mission-oriented RDIs? Surely not the Ministers of State whose offices mandate the RDIs. Surely not other government officials, no matter what their level or influence.

1.76 No, ultimately the users, or clients, of mission-oriented RDIs are the private individuals, farmers, small retailers, manufacturers, homemakers and other citizens who can ultimately benefit from the derived technology.

1.77 But do these "clients" have the opportunity (or access) to influence the choice of R&D projects, much less the plan for their completion, the allocation of resources, or the monitoring and control of all progress? And what obligation is there on the part of RDI management to work closely with this client base? The answer is, none.

1.78 Ultimately, the distinction between mission-oriented and client-centered RDIs reduces to a distinction of client accountability. The former

Who are the ultimate users of technology from mission-oriented RDIs?

Who are the ultimate users of technology from client-centered RDIs?

What are the differences, or similarities between these two user-groups?

What do we mean by "client accountability"?

are not often accountable to the ultimate users of technology. The latter are more accountable.

1.79 The greatest weakness for so-called mission-oriented RDIs is their apparent detachment from the ultimate users of the technology they are supposed to generate.

1.81 **Productive R&D:** As a consequence, we, in this and other **Management Manuals for Productive R&D**, refuse to use this distinction. Instead, we focus on how to manage RDIs so that they actually produce technologies which actually have some desired effect on national development.

1.82 All RDIs have this need. And whether they answer primarily to government or businesses in the private sector, all RDIs can become more productive.

1.83 The theme of "productive R&D" has five principal elements which will serve as the rallying points for all management strategies that follow in this, and related, courses of instruction:

- Specification and clarification of user needs for R&D;
- Specification and identification of user role in technology development;
- Adaptation and transfer of new technologies from the RDI to the ultimate users;
- Implementation of the technology by users and RDI follow-up; and,
- Impact of RDI derived technologies on national development.

1.84 In other words, all RDIs, whether mandated by government or private enterprise, must develop and maintain the closest possible, functional relationship with the ultimate users of technologies which derive from them.

1.85 It could be argued that we equate productive R&D with client-centered R&D. And that argument would be acceptable if its

Why is client accountability important in ensuring the ultimate productivity of an RDI?

What is meant by "R&D productivity"?

How do you know when an RDI is being productive?

How do you know when an RDI is NOT being productive?

What are the ultimate criteria for "productivity"?

proponents are willing to include government RDIs among those to whom the term client-centered applies.

1.86 In sum, the purpose of this course of instruction is to provide special management techniques which will improve the productivity of RDIs whether they work directly with users in the private sector, or whether they work for users in the private sector through governmental intermediaries.

1.91 **Confidence in R&D:** The catalytic relationship between R&D and national development, is based on the confidence that R&D can make a contribution to provision for the basic human needs of all segments of the society. There is no doubt that areas of the globe which have lagged behind technologically are also weak politically and economically, and as a result, poverty-stricken. Scientists as a whole, and applied researchers in particular, have a duty to ensure that they deliver useful technology. On them rests the responsibility to convince policy makers and financial allocators that R&D benefits national development. R&D results must be convincingly presented so that they enhance mutual understanding and confidence in the role of R&D in national development. It is only in a climate of confidence that scarce financial resources will continue to be allocated to R&D.

Conclusion: R&D is a catalyst for national development. It must forge a close link between policy makers, resource allocators, researchers and the clients for technology. Such links will create the climate where resources, scarce as they are, can be allocated so that R&D plays its legitimate role in national development.

What are the significant relationships between the following three factors:

- R&D productivity
- RDI clients
- National development

Try answering these questions by relating them to your own RDI.

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*MANAGEMENT MANUAL FOR PRODUCTIVE R&D:
R&D STRATEGIC AND PROJECT PLANNING AND BUDGETING*

CHAPTER II

R&D MANAGEMENT

R&D MANAGEMENT

Training Objectives

By the end of this chapter, the participants will be able to:

1. Define R&D management.
 2. Explain the seven elements of R&D management.
 3. Distinguish three elements of the RDI management system and tell how they relate to each other functionally.
 4. Identify and differentiate three kinds of R&D managers.
 5. Explain the role of decision-making in R&D management.
 6. List and define a dozen topics that comprise an R&D management curriculum.
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R&D MANAGEMENT

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All of this material can be covered in one session, if it has been studied on an individual basis prior to the session.

CHAPTER II

R&D MANAGEMENT

Good management practices are imperative for the success of any venture, especially to increase the effectiveness of available resources in an era of shrinking resources and competing claims. Lack of awareness and insufficient attention to management concepts have proved to be a major factor in the unsuccessful outcome in many of the development endeavours of Third World countries. This is particularly true in activities relating to science and technology for development. (Shihab-Eldin)

2.11 **Introduction:** R&D management remains one of the least developed, but most essential, capabilities in the R&D enterprise. Most professionals approach R&D with advanced training and experience in the subtleties of science and technology. Most of them are able to conduct very sophisticated studies.

2.12 But what happens when a group of them are brought together with the expectation that , their team efforts will exceed what they could accomplish individually? What happens when they all become dependent on resources emanating from a single administrative superstructure? What happens when that superstructure not only controls resources for their work, but also their technical goals and priorities? In sum, what happens when scientists and technologists who were trained, for the most part to

How many trained researchers, scientists, and technical assistants work in your RDI?

How many of them were trained especially to work with a team of researchers on interdisciplinary projects?

In contrast, how many of them were trained to work relatively independently on research projects of their own design and interest?

How many of them were given some training in general management; or

work individually, are organized into any enterprise of which is expected corporate productivity and resource accountability?

2.13 That is the point at which the scientific pursuit of technology obtains a character which many researchers find totally unacceptable. Others, who recognize the importance of organized-science for national development, spend the largest portion of their careers adapting to it. Some of them even accept the challenge of leaving their laboratories, micrometer screws, vials and other scientific instrumentation, for the typewriters, telephones, memoranda, financial reports and swivel chairs of R&D management.

2.14 It remains for these few to develop the technology of R&D management. Few universities around the world offer such course work. And few programmes in business schools are directly applicable to the unique character of management problems in R&D. So we are here to share our successful R&D management practices.

2.21 **Definition:** “R&D management”; what does it mean to you? Telling research scientists what to do? Maybe hiring them in the first place? Making decisions about the purchase of scientific equipment and supplies. Publishing the results of R&D projects? Winning a commendation from the government for R&D contributions to national development?

2.22 Who should be responsible for evaluating the quality of R&D project proposals—and selecting those which will be funded by the RDI? Who should monitor the technical performance of each RDI project—and nudge someone when those projects deviate from planned schedules or costs? Who should discover the country's highest priority needs for technical solutions to development problems—and incorporate the potential users of R&D solutions into the research management process?

2.23 R&D management is all of these things—and more. R&D managers are all people in the RDI—not only the small cadre whose job descriptions include more management functions than

research management, in particular?

On the other hand, how many managers in your RDI, were once (or maybe still are) researchers?

How well have they adapted to the management role?

Take a moment to rapidly list as many "R&D management" tasks as you can—right here, on these lines:

[illegible]

What is the difference between "R&D

scientific or technical ones. For the purposes of this workshop, and all others in the **Management Manual for Productive R&D** series, R&D management is defined as depicted in **Figure 1**.

tasks" and "R&D management tasks"?

Figure 1. A Comprehensive Definition of "R&D Management"

R&D MANAGEMENT

The efficient and effective mobilization and control of human, material allocation and financial resources in a manner which perpetuates a creative environment in which research and development activities may be used to focus technology on priority national development problems.

2.241 This definition has seven significant elements. Each of them deserves special consideration. All seven are:

1. "...efficient and effective...."
2. "...mobilization, allocation and control...."
3. "...human, material and financial resources...."
4. "...perpetuates a creative environment...."
5. "...research and development activities...."
6. "...focus on technology...."
7. "...priority national development problems."

Let us dissect each of these elements so that we all commence this study with a common understanding of our principal subject.

2.242(a) **Efficiency and Effectiveness:** These are very common words in the management lexicon. Efficiency usually implies both speed of execution and parsimony in the expenditure of money and other resources.

*When is some process "efficient"?
How can you tell?*

What are the special characteristics of efficiency?

2.242(b) It is not difficult to comprehend the meaning of this term when it is applied to the management of such standard operations as manufacturing. But it acquires increased significance when applied to the field of R&D.

*Can R&D work be done efficiently?
How ?*

2.242(c) This is because both time and resource limitations are traditionally considered the enemies of scientific and technological pursuits. Some of the greatest scientific and technological contributions to humankind have absorbed largely uncontrolled quantities of resources over time periods which were determined only by the nature of the research, the scientific capabilities of the researchers, and technical progress.

2.242(d) It was the Second World War which really brought efficiency into the technical laboratory as one criterion for success. Of course scientists and researchers then were applying their expertise to the preservation of basic human values and a style of life for which they were willing to give-up life.

2.242(e) Quite obviously time and resources became critical elements of the R&D management process. They were made manifest in the development of an R&D management technology called "operations research."

2.242(f) Since then, the number of scientific and technical contributions to life on Planet Earth have increased geometrically—and the rate of growth continues to escalate. But resources are, at the same time, becoming scarcer—hence even greater pressure for efficiency in R&D.

2.242(g) "Effectiveness" is also widely understood. It usually means that a person, thing, or process actually accomplishes intended results. But like "efficiency", effectiveness has special significance in the field of R&D. This is because, the traditional bastions of research, universities and other scientific centres, frequently placed greater importance on research methodologies, than on research results.

2.242(h) But those priorities change in R&D work where the emphasis is on applied research. In an RDI researchers are working to solve real problems of society. They use scientific and research methodologies—as do university researchers. But their purpose is to effectively enhance national development. Therefore effectiveness becomes a very important criterion for the conduct of work in an RDI.

*When is some process "effective"?
How can you tell?*

What are the special characteristics of effectiveness?

*Can R&D work be done effectively?
How?*

2.242(i) We wish to emphasize the importance of the concept of R&D effectiveness. The theme of this management training is "Productive R&D". That means, R&D which actually enhances national development. All of the management concepts and processes discussed in this manual stress managing the R&D enterprise so that priority national development problems are solved. Very few RDIs are, or should be, in the business of generating research results for their own sake.

2.243(a) **Mobilization, Allocation and Control:** These, too, are standard management processes. "Mobilizing" means obtaining or acquiring; and it refers specifically to all those resources which are needed to conduct useful R&D.

2.243(b) Mobilizing is a special talent. Frequently it requires an R&D Manager's ability to befriend and persuade senior government officials of the importance of the R&D enterprise. In fact, many researchers who accede to management positions are frequently startled to discover that the responsibility for obtaining financial resources entails a great deal of personal, representational activity.

2.243(c) These can include the ability to write effective letters and give persuasive speeches; to explain research to non-researchers; and to compete effectively with other government heads who also seek funding for activities which are totally unrelated to the R&D enterprise.

2.243(d) "Allocation", on the other hand, is what happens to those resources after they are acquired from government or other sources. Allocation is the process of deciding how those resources should be spent, i.e., for which R&D projects, and in what proportions.

2.243(e) Obviously, since resources are always limited, not all proposed R&D projects can be funded in any given year. Therefore, R&D managers must decide how to distribute the limited resources among the proposed projects. This is accomplished, in part, through evaluation of the merits of proposed projects. It is also, in part, a function of astute project planning. For

List some of the resources you have to "mobilize", in your official role in the RDI:

*Does everyone in the RDI have to mobilize some resources?
Explain!*

*What resources do you allocate?
List them here:*

*Does everyone in the RDI have to allocate some resources?
Explain!*

example, a project which is carefully phased over a couple years requires less per-year funding than it would were it proposed for execution in one year.

2.243(f) Allocation is management decision making—in its purest sense. It requires the capabilities of astute evaluation, sensitive negotiation, clear communication and decisiveness. Quite obviously too, there is a large element of risk in it. What if the project which received the allocation, failed miserably? That is highly likely in the R&D business. R&D is nothing if it is not uncertain in many respects. But that uncertainty does not mitigate the importance of management. On the contrary, it reinforces the value of making tough decisions—like those associated with resource allocation.

2.243(g) “Control” is a term which strikes fear in the hearts of many researchers. This is because it implies significant restraint on the creative processes which underpin R&D. Yet, it is required in R&D management because of severe resource limitations.

2.243(h) After resources are allocated to R&D projects, their rate of absorption must be monitored in comparison to the technical productivity of the project. If, for example the rate of absorption exceeds expectations, then perhaps completion of the project is in jeopardy. It is far better to know that before the project reaches a resource crisis because it may be possible to bring more resources to bear if the outcomes of the project merit it.

2.243(i) Control is the process of deciding how to change the rate of resource absorption, or technical work, in order to obtain the greatest project efficiency and effectiveness. Quite obviously, it can involve some very sophisticated management techniques. But even more important is the interpersonal sensitivity with which management control is exerted on the project and the people who are responsible for it. Too much control, poorly conceived and delivered, can inhibit the creative spirit of the best R&D people. It can have an effect on institute productivity which is opposite to that which is desired.

What do we mean by "control"?

How does the concept of control relate to resources for R&D?

Why is control such a difficult concept for some R&D technical people to fully appreciate when it is applied to R&D management?

After all, they have little difficulty with the concept of control when it is applied to laboratory experimentation!

What are the differences and similarities between management control and research control?

How can we help R&D technical people recognize that management control is just as important and desirable as experimental control?

2.243(j) On the other hand, lack of control in an RDI can lead to a total breakdown of technical and management discipline—hence R&D productivity. Management control of R&D requires a very sensitive, if firm, hand on all activities in the RDI. It is a function which all RDI personnel must be prepared to exercise, in their own domain; at their own level.

2.244(a) **Resources:** Resources represent the “cost” of productive R&D. They are the “inputs” to the R&D process. They are well defined, and known. In contrast, the “outputs” of productive R&D frequently remain unknown until the project is completed.

2.244(b) Resources include:

- People—whether highly trained scientists or labourers;
- Raw materials and supplies;
- Instrumentation and equipment;
- Buildings and grounds; and,
- Money.

In short, resources for which R&D managers are responsible include everything that is required to conduct R&D work.

2.244(c) This even includes time. The effective use of time is crucial for the undertakings of an RDI. The effect of time limitations on scientific and technological pursuits is often recognized; but the cost element of time lost, or wasted, is often glossed-over. One of the critical resources of any RDI is time and it requires astute management.

2.244(d) Now the techniques for managing resources vary with the nature of the resource—among other things. For example, managing people requires interpersonal and emotional sensitivities which are not as frequently needed for managing inventories of raw materials.

How can time be considered a “resource” for R&D work?

What kinds of controls can an R&D worker exert on time?

What do we mean by “time management”?

2.244(e) As a consequence, R&D management includes a variety of resource management technologies; hence, different managers are frequently assigned to different resources. Accountants help manage money. Personnel specialists help manage people. Equipment specialists look after the RDI's specialized equipment and facilities.

2.244(f) It is the astute management of resources which goes the furthest toward ensuring the productivity of R&D. Resources fuel the R&D process; without them the process dies.

2.245(a) **Creative Environment:** Researchers and scientists are the first to point out that their activity requires the unfettered liberty to "create", to originate ideas and processes. Too often, that is offered as a justification for lax management—a condition which rapidly exhausts all resources for R&D.

What do we mean by "creative environment" for R&D work?

What are the characteristics of a creative environment for R&D:

2.245(b) Therefore, RDI managers are faced with a delicate balancing act. How is it possible to stimulate creativity and the freedom to generate unique solutions to development problems; while, at the same time limiting resource expenditures and controlling R&D processes?

2.245(c) The most common sources of breakdown in the relationship between RDI scientists and administrators is imbalance or disequilibrium between needs for a creative environment, and controls on R&D resources. One of the objectives of this series of R&D management manuals is to demonstrate that a solution to this problem lies in sharing management responsibilities for control, with the scientists who are also responsible for research. Theirs is the capability to create needed balance.

What are the institutional and organizational threats to a creative environment for R&D?

What can be done to help ensure the creative environment for R&D?

2.246(a) **Research and Development Activities:** These, of course, are the most obvious activities around any RDI. These are the technical activities which lead to productive solutions to the nation's development problems. These are the activities which require the specialized knowledge and skill of trained scientists and researchers.

2.246(b) But we would like to emphasize that they comprise only one of the seven vital elements in our definition of R&D management. They comprise only one-seventh of the concepts, issues, processes and products we will address in this management training workshop.

2.246(c) In this discussion, we will not talk about particular R&D technologies; we will not focus on scientific methodologies of inquiry. Rather, we will be talking about how all RDI personnel may improve the probability that R&D activities lead to productive technological innovations for national development. We will be talking about how to increase their productivity through the judicious allocation and control of scarce resources.

2.247(a) **Technology:** Technology is used, here, in a most general sense. It refers to the science of controlling forces, both natural and social, to produce desired effects. Interesting, isn't it, that the word "control" comes up again. It is key to the purpose of RDIs. It is also key to managing productive R&D.

What do we mean by "technology"?

How do the concepts of technology and control relate to each other?

2.247(b) RDIs are designed to help society learn to control the forces which impact it. Technology is the collection of knowledge and processes which give society that leverage. Technology is the sometimes elusive target of R&D.

2.247(c) In this course of instruction we use the term in its widest sense. It applies to knowledge in any area: agriculture, education, manufacturing, housing, theology, fisheries, business economics, aerospace, textiles, mental health, transportation, military science, or anything else. The important point is that the RDI practices R&D methodologies for deriving, or adapting, knowledge which will further economic development in the country.

2.247(d) Technology is never, here, meant to limit areas of knowledge to those associated with the worldwide micro-electronics industry.

What are some principal development problems in your country?

2.248(a) **National Development Problems:** This is the last, but far from the least important, discriminator in our definition of R&D management. In many ways, the concept of national develop-

ment in R&D management relates directly back to the first discriminator we discussed: “effectiveness”.

2.248(b) Throughout this R&D management manual, and others in the series, we presume that the ultimate purpose of RDIs is to further the economic and social development of the country. In contrast, we are not presenting R&D management strategies which are particularly necessary to increase profits in some industrial sector.

2.248(c) So, by “effectiveness” in the first discriminator we are referring to reducing illiteracy, poverty, sickness, malnutrition, unemployment and other conditions which inhibit the society’s pursuit of life; liberty and happiness for all people.

2.248(d) While ambitious, this is a goal which every RDI manager (including, especially, scientists and research workers) must keep in mind. It is a goal which must be renewed every year during the annual programme planning cycle.

2.31 **RDI Management:** Throughout this course of instruction we are talking about the management of R&D in organizations called, “Research and Development Institutes” (RDIs). In any given case they may be called something else; but we use this term to refer to all variations on the same theme.

2.32 An RDI is a very special place in a variety of respects. No other organizations have the exclusive mandate to generate new technology for the sake of national development. And while it is a very demanding and challenging enterprise, it is also exciting to be part of such a venture. The excitement comes from the challenge of the unknown. Add to that the potential to accomplish significant improvements in the lives of the people, and we have the ingredients for extremely worthwhile and personally rewarding careers for all RDI personnel.

2.33 But, let us take a look at how RDIs function. What are their major functional elements? How can we generally differentiate the

What are some of the principal development needs—to solve these problems?

Which ones are R&D institutes working on right now?

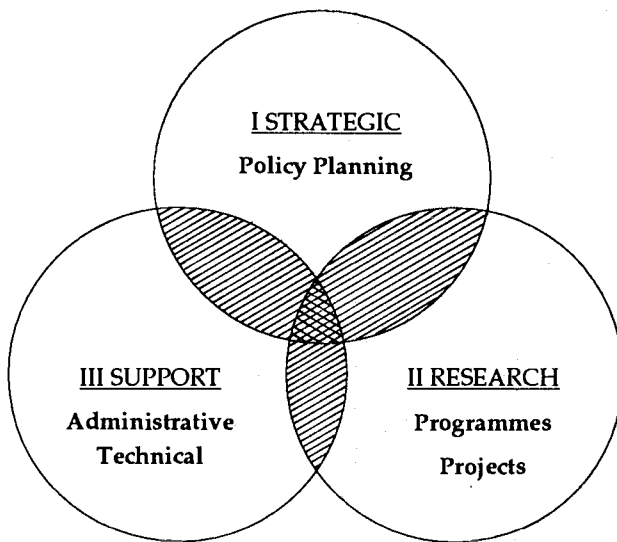
What are the chances that the RDIs will come up with some answers for these development needs?

What is the relationship between RDI effectiveness, and national development?

skills and duties of the principal people who work there?

2.34 For this purpose we turn to the thinking of a Brazilian expert in R&D management, Professor Jacques Marcovitch (Russell). He offers a pictorial model of an RDI which is depicted in Figure 2, below:

Figure 2. Marcovitch Model of an RDI



2.351 The Marcovitch Model depicts three principal functions in any RDI. They include strategic policy and planning (Circle I); research programmes and projects (Circle II); and administrative and technical support (Circle III).

2.352 Strategic policy and planning (Circle I) includes those duties and people which try to keep track of the long range goals of the RDI; the priority development needs of society, which R&D work can probably help fulfill; the resources needed by the RDI to accomplish the R&D work; and the RDI's relationships with principal constituents of its effort.

2.353 Research programmes and projects (Circle II) include the actual focus of technical activity in the RDI. These are the people and R&D activities which are designed to generate the innovative technology for national development. These are the specific programmes and projects which are designed to help fulfill the strategic goals developed and monitored by managers operating more in the domain of Circle I.

If you had to pick one element of an RDI which was most important for overall technical productivity, which of these three would it be:

- policies and plans
- programmes and projects
- administrative and technical support

Explain your answer!

2.354 Circle III represents a collection of RDI offices and functions which are indispensable to the people and activities operating in the other two circles. Administrative and technical support (Circle III) includes all those RDI people and activities which make it possible for others to do their strategic planning and research work. Functions like special laboratories, the motor pool, libraries, the accountants, file clerks and the typing pool, personnel specialists and purchasing people, inventory control, maintenance staff and computer specialists are just a few of those RDI activities which could be considered services to the strategic and research functions.

2.355 Ideally, all three functions in an RDI are well developed, complementary and well managed. But that is the ideal. More likely, each RDI maintains a unique alignment of these three functions with management strengths and weaknesses in each. The purpose of this manual is to provide ideas which will strengthen each of these three functional areas of the RDI, and the relationships among them.

2.356 Professor Marcovitch emphasizes that Circle II represents the "bottom line", or the ultimate focus of all RDI activities. This is because the R&D activities themselves, are the source of any new technologies which may impact national development. The other two functions, strategic planning and administrative and technical support, are really designed to facilitate research and development. Without R&D, there is no purpose for the RDI. And if the R&D activities are not productive, there is not purpose for the RDI. Hence Circles I and III represent RDI functions which are necessary to help ensure the productivity of R&D activities.

2.36 This is an important observation because too often RDIs fail to have their desired impact because managers forget that they are in the service of R&D. Too often, they begin to act as though R&D activities and personnel exist to further the careers and status of managers in the other two functional areas.

What is the role of administrative and technical support people in an RDI?

In which of these three elements of an RDI will you find "R&D managers"?

Hint: Be careful! The answer is not as obvious as it may sound in the question.

Which of these three elements has the closest and most critical relationship to the clients of R&D?

Explain your answer!

Where is the emphasis in your RDI—on top management, or on technical productivity of R&D programmes and projects?

2.37 In such cases, the RDIs become very bureaucratic; or management becomes highly centralized and authoritarian. This usually leads to severe morale problems for research people. And that, in turn, leads to the RDI's loss of good researchers and inability to attract new ones. Ultimately, R&D productivity suffers, and the RDI becomes just another expensive government agency which serves no useful purpose for society.

2.38 Therefore, the purpose of this training material is to stimulate sound management practices among all functional elements of the RDI. Further, it is our intention to emphasize that all people in all functions are responsible for some aspects of management in the RDI. In other words, we will not tolerate the artificial distinction between "researchers" and "managers." That is the kind of thinking which leads to a severe breakdown in an RDI.

So, in the ideal RDI who are the R&D "managers"?

As a consequence, who do you think would benefit from R&D management training in a programme like this one?

2.39 Instead we will be focusing on management practices which are well within the purview of research workers. In fact, many of the management tasks in an RDI, like planning, budgeting, monitoring and controlling, cannot be done successfully without the primary input of personnel who normally function within Circle II (R&D projects and programmes). That leads to a discussion of targets for this course.

2.41 **R&D Managers:** The targets for the course of instruction are any RDI personnel who have the slightest amount of decision making responsibility. That is regardless of their sector of activity within the RDI. Therefore the term "research managers" includes a vast array of people.

2.421 One of the most important groups of RDI personnel is the research workers. These are the people who create the RDI's end-products well or poorly, on time or late, within cost or with cost overruns. Without research workers, the best RDI planning strategies and administrative support will not improve institute impact on development.

2.422(a) Therefore, we propose that "researchers" are one target for this management training. We operationally define them as follows:

Researchers are those research managers who are primarily responsible for the output of the RDI through:

- Bringing specialized technology to bear on the resolution of national development problems;
- Proposing, conducting and reporting research projects; and,
- Furthering the technical productivity and capability of the RDI.

2.422(b) The most significant characteristic of researchers is their technical specialization. Most of them come to the RDI from academe where they learned the requirements for basic research. Few of them on the other hand, will have experienced training on the principles and practices of sound management in any enterprise. Most of them will have acquired these only through experience, to the extent they know them at all.

2.431 Therefore, every RDI will also comprise a group of less technically-oriented managers who are primarily responsible for selecting R&D programmes to receive scarce resources; planning the general direction of the RDI; appealing to government funding sources for support; and ensuring that the RDI's mandate is fulfilled. We therefore call these people "strategic managers."

2.432(a) Strategic managers give the RDI a sense of direction. They bridge the vital gap between the RDI's technical capability and the nation's development goals and priorities. They are, therefore, a most important target for management training. We define "strategic managers" as follows:

Strategic managers are those research managers who are primarily responsible for directing the whole R&D activity through:

- Ensuring that the R&D activity coincides with national development priorities;

Who are the "researchers" in your RDI? How many are there? What is their level of technical training?

How much management responsibility do they have?

How much do they want?

How happy are they working in your RDI?

How productive are they in your RDI?

How many strategic managers does your RDI have?

- Mobilizing the human, material and financial resources needed to carry out the work of the RDI; and,
- Establishing the fundamental rules and standards by which all RDI activities will be managed.

What is their level of training for the management job?

How much research education and experience do they have?

How much management experience do they have?

2.432(b) Strategic managers generally operate at the top of the RDI hierarchy. We hasten to add that this is not because they are, in some way, better or more important than researchers. Rather, it is because there they are more accessible to important people and organizations which exist outside the RDI, and which are the principal sources of R&D needs plus finance, material and other supplies required to fulfill them.

How happy are they in their management position?

What are their principal management skill needs?

2.432(c) *Many of the strategic managers have research and technical backgrounds. Many of them, therefore, have a good understanding of the institutional requirements for successful R&D. With these strategic managers, training can help them adapt management techniques to the R&D environment.

2.432(d) But other strategic managers may already embody sound management knowledge and experience; but may lack the R&D technical knowledge. They, for example, may have originated from the ranks of the civil service, in some other agency of the government. Training can help these people adapt their bureaucratic skills to the R&D environment. It can help them learn when and how to rely on technical researchers for management decisions. It can help them learn how to work together.

2.441 A third group of research managers can also be found in most RDIs. These are the critical support staff. They may have a management background like accountancy or purchasing. Or, they may have some research technical skills like statistics or laboratory management. But they are distinguished by the fact that their role is usually limited to one or two duties which are needed to support the functions of the researchers or strategic managers. We classify these personnel as support staff and define them as follows:

Support staff are those research managers who are primarily responsible for supporting strategic and research activities by:

- Collecting, combining, analysing and interpreting information on all institute operations;
- Converting institute policies to management systems; and,
- Facilitating the relationship between institute policy makers and researchers.

2.442 Support staff are responsible neither for establishing the RDI's strategic direction, nor producing its technical results. They are, basically, helpers for the other two types of research managers. This does not, in any way, mitigate their importance. Can you imagine an RDI without a library, or computing capability; without a secretarial pool or maintenance department?

2.443 For the purposes of this training we call all three target audiences "research managers". This material is appropriate to all three of them. For a smoothly functioning RDI it is vital that all three understand the entire array of R&D management capabilities, and that they know not only how to conduct their own management responsibility; but also that they know what kinds of management responsibility to expect from managers in the other groups.

2.444 An RDI is a social system in which strategic managers, researchers and support staff work and interact. Each group has its own characteristics, attitudes, values and norms. In such a situation conflicts are bound to arise due to limitations in resources and competition for them; disagreement over goals, as well as ways and means for fulfilling them; unwelcome rules and procedures; and even, external pressures.

2.445 Part of the RDI management process is handling such conflicts through creative problem solving. It is a process of joint diagnosis, analysis of alternatives and decision-making about a final solution.

How many support staff are there in your RDI?

What are their principal duties?

Who do they "support"?

What kinds of management roles do they play?

How do they relate to strategic managers and researchers?

How do these other two groups feel about them?

2.51 **Decision-Making:** Fundamental to any management function, activity, or problem solving is the process of decision-making. It is so fundamental that some people equate it with management.

Can you outline the major steps in any decision-making process?

List them here:

2.52 **Managerial decision-making** is a rational process of arriving at a conclusion. It starts with a clean statement of a problem which must be solved, and ends up with a choice among alternative solutions. Following are some of the general steps involved in decision-making:

What does "defining the problem" have to do with "making a decision"?

- Defining and stating the problem(s), and the goal(s) to be attained by solving it;
- Examining the characteristics, strengths, weaknesses, opportunities and constraints inherent in the problem and the environment which impacts it;
- Identifying the full range of alternative solutions and working out the pros and cons of adopting each of them; and,
- Selecting one of the alternatives and implementing it.

R&D management is decision-making by strategic managers, researchers and support staff.

2.61 **R&D Management Topics:** What kinds of topics comprise management training? What kinds of management training would you like for yourself, or for your RDI colleagues? Some of the standard management topics appear in the quotation which opened this chapter.

What management topics for training would be most helpful to you, in your position in the RDI?

List them here:

2.62 If we were to rely on the traditional general management literature we would offer training topics like: planning, staffing, organizing, directing, monitoring, controlling and evaluating. Those are all important topics and we would be pleased to discover RDI managers who have studied them.

2.63 However, we also feel that it would be more useful to provide management training which is more specifically adapted to the special

character of management in an RDI. What kinds of special management problems occur in RDIs? And which ones are unique to RDIs in developing economies? That is the focus of this series of management manuals.

2.64 Our experiences with managers in a variety of RDIs, suggest that at least the following 14 management topics would be useful:

1. R&D Policy Development
2. Planning and Budgeting for R&D
3. RDI Financial Management
4. R&D Organization Development
5. R&D Institute-Client Relations
6. R&D Institute Communications
7. R&D Institute Information, Documentation and Management Information Systems
8. R&D Project Selection
9. R&D Institute Personnel Management
10. Co-ordination of R&D Functions
11. Material, Facilities and Inventory Management
12. Monitoring and Controlling R&D
13. R&D Technical Methodologies
14. Evaluating R&D Performance

Write to us telling us of your specific R&D management training needs. We will see how we can help.

*Our address appears on the title page of this **Manual**.*

Can you think of others which would improve management in your RDI? Which of these is most important to you right now?

2.65 Careful analysis of each of these topics suggested the titles of nine management manuals. They are:

1. **R&D Strategic and Project Planning and Budgeting** (A combination of numbers 2 and 3, above.)
2. **R&D Finances and Financial Management** (Combines elements of 2, 3, 7, 8, 12, and 14.)
3. **Commercialization of R&D** (Relates to the transfer of derived technology from the RDI to the end-user.)
4. **R&D Management Communications** (Focusing on particular methods and techniques like number 6, above.)
5. **R&D Institute-Client Relations** (Dealing with constituents at both the strategic and end-user level, like number 5 above.)
6. **Project Planning, Monitoring and Control** (Focusing on how to direct the course of R&D; number 12, above.)
7. **Facilities, Material and Inventory Management** (Detailing specialized management techniques for these applications; number 11, above.)
8. **Personnel Management** (Highlighting the processes of recruitment, selection, direction, evaluation, and compensation; number 9.)
9. **Scientific and Technical Information and Management Information Systems** (Focusing on this vital resource for any RDI; number 7, above.)

2.66 Of course, none of these titles can be fairly treated in isolation from the rest. R&D management is nothing if it is not a holistic process. Each topic depends for its success on the successful practice of every other topic. In fact, even in this manual you will find that many of these topics arise during the discussion of planning and budgeting.

2.67 Successful R&D management depends on the fully integrated functioning of every research manager, throughout all three functions of the

RDI. Also, success with any of these topics depends on adequate understanding of the processes and capabilities of every management topic.

2.68 R&D management will be successful to the degree that it involves all institute personnel in all management processes.

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*MANAGEMENT MANUAL FOR PRODUCTIVE R&D:
R&D STRATEGIC AND PROJECT PLANNING AND BUDGETING*

CHAPTER III
ORGANIZING

ORGANIZING

Training Objectives

By the end of this chapter, the participants will be able to:

-
1. Define organization.
 2. Specify the purpose of an organization chart and define its principal parts.
 3. Draw an organization chart which best represents their own RDI.
 4. Explain the significance of eight principles of organization.
 5. Describe the relative merits and demerits of centralized and decentralized organization structures for R&D management.
 6. Explain the ultimate criterion for the success of any form of organization.
 7. Differentiate three types of organizational structure in terms of their efficacy for R&D management.
 8. Draw their own RDI as a matrix organization.
 9. Describe the role of human relations in making any form of organization work well.
-

ORGANIZING

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SESSION BREAK

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All of this material could be covered in one session, if it has been studied on an individual basis prior to the session. However, the difficulty of some of the concepts might justify breaking it into two sessions, as noted.

CHAPTER III

ORGANIZING

If research workers are left entirely to their own initiative, there is risk of anarchy, sterility and waste of time and money in useless research and abortive projects. But, if a research assignment is forced into a rigid structure, and oversupervised, the researcher's creative spirit tends to disappear; workers become afraid to show initiative; and they become mere cogs in a bureaucratic machine which loses any capability for original work. (Pons)

3.11 Introduction: There is a need to balance freedom and organization, particularly in an RDI. These may seem to be contradictory forces but they can and must be reconciled. When either of them gains the upper hand, research is paralyzed. If research is properly organized and managed, it will avoid these two dangers and thus foster an atmosphere in which the creative spirit can develop freely. Organization is not an end in itself! It is at the service of the research worker. Its task is to strike a balance between the needs of the researcher, and those of the RDI in which the researcher works.

3.21 Definition: Organization is the structure of relationships, among personnel, financial and material resources, that are designed to accomplish specific set of objectives. The ultimate success of any form of organization depends on the accom-

plishment of the functional objectives of the people who are organized.

What do we mean by "Organization"?

3.22 In an RDI, organization is the structure of relationships among strategic managers, researchers and support staff—all of whom are bent on the accomplishment of a variety of R&D objectives.

How do we know if a group is "organized"?

Does an "organization chart" tell you how well a group actually works together? Explain?

3.31 **Organization Design:** It is common practice to draw the structure of an RDI by means of something called an organization chart. It is a chart which may be used to show:

- Structure of the RDI
- Reporting relationships
- Flow of work
- Areas of responsibility

What is an organization chart?

Why do we draw them?

How are they drawn?

3.32 The organization chart is drawn for two purposes: (1) to help employees of the RDI understand the structure of the RDI, levels of authority, and the reporting chain; and (2) to give outsiders the same understanding. The organization chart shows the formal RDI structure. It rarely shows R&D project management structure; and it never shows the informal structure.

Can you draw one for your RDI?

3.33 The organization chart is composed of a series of blocks which are connected by lines both horizontally and vertically. Boxes connected vertically indicate lines of authority; they are called line functions. Boxes connected horizontally indicate areas of responsibility without changes in authority; we call these staff functions.

3.34 Look at the two organization charts in **Figure 1** and analyse the meaning of differences between them. Answer these questions:

Put an X in one correct box for each question

1. In which one does the RDI Director have the greatest span of control?
2. Which would you guess is the newer RDI?
3. Which has the longest chain of command?

RDI # 1

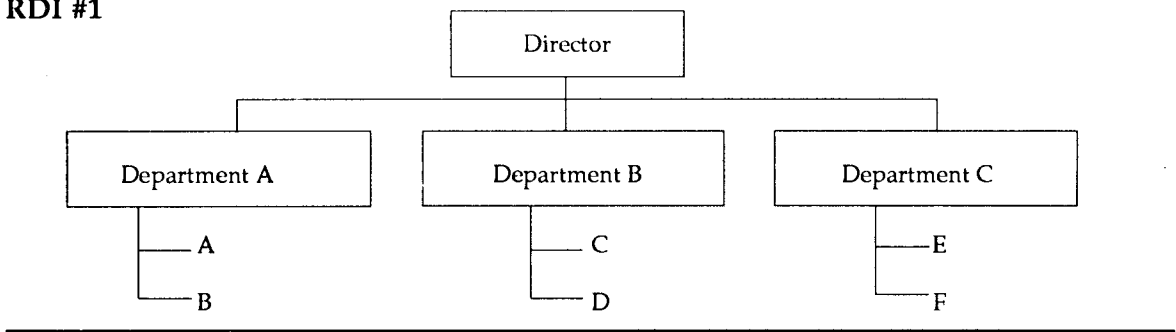
☐
☐
☐

RDI # 2

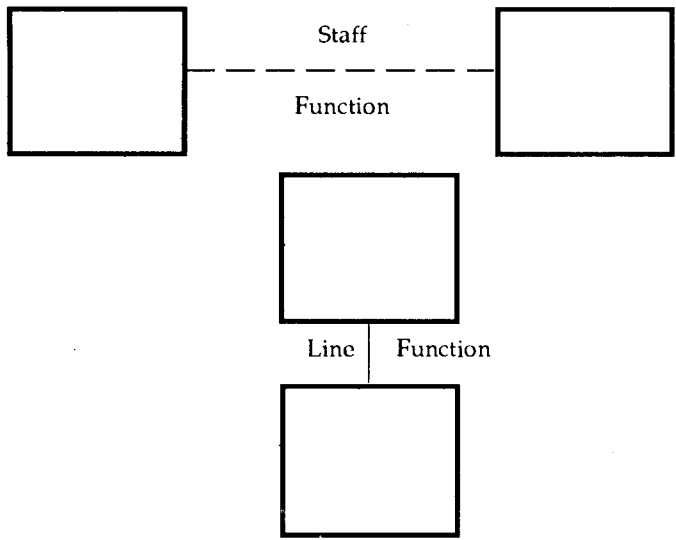
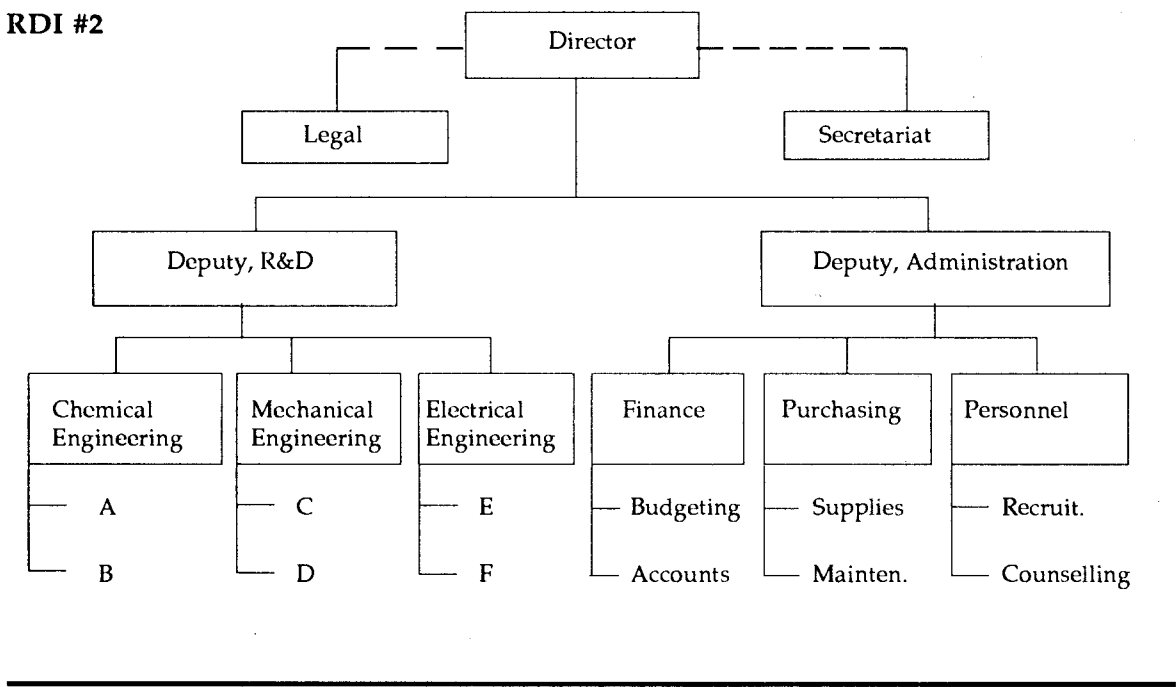
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Figure 1. Two Organization Charts

RDI #1



RDI #2



- | | | | |
|----|--|-------------------------------------|-------------------------------------|
| 4. | In which one do Department Heads have the greatest range of duties and responsibilities? | RDI # 1
<input type="checkbox"/> | RDI # 2
<input type="checkbox"/> |
| 5. | Which has Department Heads with narrower scopes of responsibility? | <input type="checkbox"/> | <input type="checkbox"/> |

3.35 In addition to showing the structure of the RDI, the organization chart tells something about the character of the RDI. Structures with little vertical depth indicate short chains of command. In them the major Departments work as relatively autonomous units—though they are under the direct control of the RDI Director. This flat structure is characteristic of most new RDIs—in their early stage of development in which duties and responsibilities are not very well separated. Each Department Head is likely to have a broad scope of responsibility.

Chain of command: This means the vertical depth of the organization chart—the number of command levels.

3.36 In a more mature RDI, on the other hand, work areas are more specialized and separated into different units, or divisions. Heads of Departments in RDIs with more vertical depth usually have narrower scopes of responsibility than their counterparts in “flat” RDIs. Further, as the RDI grows and adds more levels of management, it also grows horizontally, thereby increasing the RDI Director’s span of control. The answers to the above five questions are:

Span of control: This refers to the director’s extent of direct management influence as reflected in the horizontal spread of subordinate units in the organization chart.

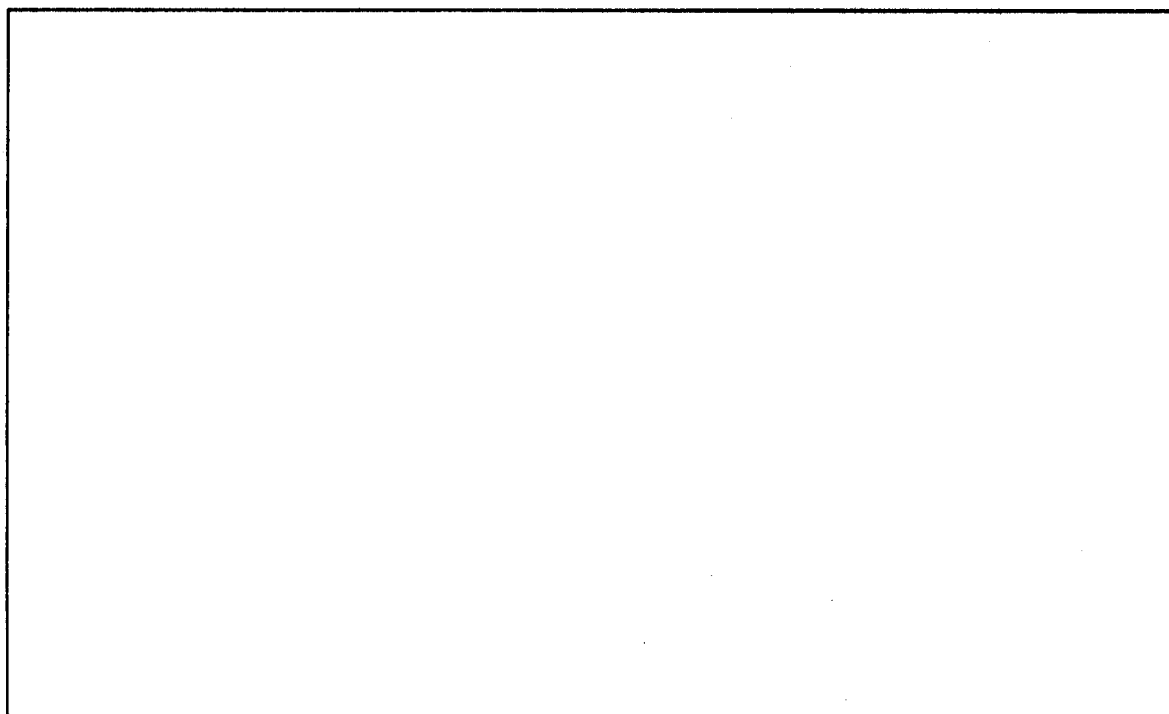
Question No.	Answer
1	RDI #2
2	RDI #1
3	RDI #2
4	RDI #1
5	RDI #2

Exercise 1: Your RDI Organization

On some note paper, practice drawing the structure of your own RDI, until you are sure you have the design which best represents it. Be sure to include at least the following five elements:

- The RDI's Governing Body (Ministry, Board of Directors, Company, Product Association, etc.)
- RDI Director
- All principal departments
- Key staff offices
- R&D project management levels

Then make a final drawing of the structure of your RDI here.

**Exercise 2: Interpreting RDI Structure**

Meet with no more than three other participants who come from different RDIs. It is important that none of you work in the same RDI. Lay all of your group's RDI organization charts, side-by-side, in the middle of the table. Examine them and discuss their similarities and differences.

Then each of you should take a turn holding up your own chart and explaining the principal elements of your RDI's structure to the rest of the group. Keep the explanation brief—no more than five minutes. The purpose of the explanation is to describe the organization in words, using the chart as a reference.

(Exercise 2 is continued on the next page)

(Exercise 2: Continued)

After all descriptions are completed, the whole group should discuss answers to the following four questions:

1. In which of the RDIs does the Director have the greatest span of control?
2. Which would you guess is the newest RDI? (Obtain everyone's opinion first; then reveal the starting dates for each RDI.)
3. Which RDI has the longest chain of command?
4. In which one do Department Heads have the greatest range of duties and responsibilities?

Spend no more than five minutes discussing each question. Try to obtain consensus among the group on answers to each question. Record the answers. If consensus is not possible, record the major differences of opinion and reasons for them.

[Instructor(s): Upon reconvening in plenary, ask one of the small discussion groups to present the results of their discussion to all participants. Ask the balance of the participants to comment on the small group's analysis of RDI organization charts. Devote up to 20 minutes to this plenary discussion.]

3.41 Principles of Organization: Experience in RDIs and a variety of other organizations has yielded eight principles which help in the design of the most efficient and effective RDI.

3.42 Continuous Chain of Command: All RDI authority and responsibility should flow smoothly in an unbroken chain from the RDI Director to the lowest level in the organization. The structure is a hierarchy of authority and responsibility. Each employee must be aware of their own role—its opportunities and its limitations. Violations of the principle occur when a person tries to bypass a superior; or when a person hordes responsibility and authority. Violations of this principle yield gross inefficiencies, and ineffectiveness of the RDI as a whole.

Look at your RDI Organization chart and ask yourself:

Is there a clear line of authority and responsibility from the top to the bottom of the organization?

3.43 Unity of Command: No member of the RDI should report to more than one superior, on any given aspect of the work. (Later we will see a form of organization which provides more than one boss for a researcher—but for different aspects of the work.) Violations of this principle occur when responsibilities and authorities are not

Does any worker report to more than one boss for a particular activity?

clearly defined; or when supervisors preempt the authority of others in order to gain time, influence or power.

3.44 Short Chain of Command: The number of distinct management levels in the organization should be kept as small as possible, to maintain accurate communication and quick response-time to directives.

Is the chain of command as short as practical?

3.451 Span of Control: In any RDI there is a small, fixed, number of people whom a manager can effectively supervise. That number depends on the skills, experience and role of the manager. Whatever the number, if exceeded it will tend to reduce the quality of supervision, and infringe on the time of the manager.

Do any managers have too many people reporting to them?

3.452 The span of control can be larger at the lower levels of the RDI where supervision tends to be of a more routine nature. However, near the top, where the decisions are more unique and wide-ranging, the span of control should be smaller.

3.46 Exception Principle: Decisions of a similar or recurring character should, usually, be made routinely at the lower levels of management. Whereas, unusual decisions (exceptions) should be reserved for managers at higher levels in the RDI. This principle frees more responsible managers to make the difficult decisions involving unusual or unprecedented problems that have broader implications for the whole RDI. Deviations from this principle can overtax senior managers, demoralize lower-level managers and generally create conditions that breed poor decisions at all levels in the RDI.

Do managers at all levels have sufficient authority to make routine decisions without having to seek approvals from top management?

3.471 Division: This refers to the basis on which the RDI is divided into distinct units. The goal is to structure it in a manner which provides the greatest effectiveness and efficiency in achieving the RDI's goals.

Is the RDI divided by type of activity; technical objectives; or both?

3.472 It can be done on a functional basis, in which workers and tasks of a similar nature are combined in units. Or, it can be done on the basis of similar technical objectives, regardless of the skills of workers or the nature of their tasks.

3.473 Division on a functional basis is usually better for smaller RDIs, which can better capitalize on the potential for economy through specialization. But larger RDIs may find division on the basis of commonality of purpose more efficient.

3.48 **Balance:** It is important to determine the size of the units in the RDI so that they will be comparable in performance capacities. This is particularly difficult to accomplish in RDIs where work is nonrepetitive and nonroutine. But striving for it will help ensure equitable distribution of duties and responsibilities and resources.

Are the RDI units of comparable productive capacity?

3.49 **Delegation of Authority:** This issue relates to organization. But it can operate independently. It is the question of how much decision-making authority is delegated to managers at each level in the organization. The degree of delegation really depends on the management style of institutional directors. Are they willing to share responsibility for decisions? Or do they horde that responsibility for themselves. The key to this principle is to delegate all the authority that is needed for managers to carry out their assigned duties. More than that is too much; less than that is not enough. It is a delicate balancing act. This principle relates to the issue of centralized or decentralized management.

Is authority appropriately delegated to the levels of responsibility indicated in the organization chart?

3.51 **Centralized or Decentralized:** One major issue remains in thinking about RDI organization. Should the RDI have a centralized, or decentralized management structure. This refers to the way decisions are made by management. In a **centralized structure, all decisions are made by the highest level managers.** But in a **decentralized structure, responsibility for decisions is delegated as far down the organization as possible.** Which is more desirable?

Case 1: A HIGHLY CENTRALIZED RDI ORGANIZATION

In 1983, a very large and well funded RDI which conducted R&D on a particular crop, operated with a budget in excess of \$2,000,000 U.S. They had over 250 employees, of whom more than 30 were professionally qualified researchers.

3.52 Actually there are advantages to both kinds of structure. For example:

Centralized Structure

1. Decisions are made by those people who are most responsible for the RDI.

Their organization was highly centralized. At the top, their Director

2. Central decision makers have no difficulty coordinating with each other.
3. Fewer total RDI staff are needed since administrators in the Director's office can serve all divisions of the RDI.
4. It is easier to enforce uniform standards and decision criteria.

answered to a Board. All administrative functions were staff arms of the Office of the Director. There was one Assistant Director, for Research. Under the Assistant Director was a Station Director. And, under this officer were 10 functional department heads. Strictly a vertical organization right down to the project level.

Decentralized Structure

1. Decisions are made by those people who are closest to the work affected by the decisions.
2. Decisions are made by those people who have the best knowledge and experience with the problems under consideration.
3. There is more rapid response to changes in the conditions of R&D.
4. All levels of personnel pick up some skills in management decision making.
5. There is more job satisfaction for all.

Notice how the structure paralleled the director's authoritarian style. All administrative decisions were horded by him. Otherwise they would have been housed in line, as opposed to staff, functions.

To reflect the extent of centralization, the Director commented to the author that he approved all purchases made by the RDI, "... from the most expensive mass spectrometer down to the cheapest wheelbarrow!"

3.53 So, you see, it is not a clear issue. Probably some variation between these two extremes is desirable. We can tell you some of the underlying assumptions for either extreme. A highly centralized management structure is usually based on the assumptions that:

- Research workers do not like to work and avoid responsibility;
- Any decision made, or order given, automatically filters down the structure and is implemented at the appropriate level;
- Workers prefer the security of not having to make important decisions, rather than the freedom to determine their own approach; and,
- Communication from top management down, is more important than communication from the bottom-upward, or horizontally through the RDI.

Case 2: A DECENTRALIZED RDI ORGANIZATION

In 1983, a large animal research institute with 45 professional researchers and over \$9,000,000 U.S. operating funds, used a more decentralized structure.

3.54 It is because of these assumptions that centralized management systems involve less delegation of authority. Decentralized systems, on the other hand, involve more sharing of decision responsibilities. They are based on a different set of assumptions about how people and organizations work best. They are based on the assumptions that:

- Research workers want to work and take responsibility for their own efforts;
- Researchers, in particular, need to have the freedom to influence the course of their own work;
- Shared responsibilities enrich, as well as enlarge, jobs;
- Accountability to peers is a more effective control than accountability to superiors; and,
- Workers respond better to informal and flexible norms, than they do to rigid rules, directives and regulations.

3.55 So, there is a choice for each RDI manager—no matter what level of the organization they are in. Will decision making responsibility be shared, or centralized? Neither extreme is necessarily preferable. Each RDI must develop its own style of delegation, to match its own needs and the predisposition of its managers.

3.56 Think about your own RDI; look at your organization chart, and ask yourself:

1. At what level are most decisions made?
2. What are the differences in the kinds of decisions made by the Director, and R&D project leaders?
3. Do the people in your RDI influence the course of their own work; or is it largely prescribed by top management?

3.57 Above and beyond all other considerations, we would like to stress that:

Three Directors ran the RDI—a Director General; and Director for Administration; and Director for Research. You see, even the "director's" authorities were distributed among three people. Financial control and Training were staff arms of the Director General.

Nine laboratories had one Head, each—at the third level of management. But research projects were conducted by teams composed from the personnel of the appropriate laboratories.

In contrast to Case 1, purchasing of research supplies in this RDI was supervised by Project Directors, up to a maximum financial value. Anything more expensive was decided by a team of appropriate Laboratory Heads, Project workers, and a member of the Director General's Financial Control Office.

In this decentralized structure, authority to make decisions was delegated to individuals and teams of qualified people.

The ultimate criterion for the success of any form of organization, is the accomplishment of organizational objectives. (Cohen)

For an RDI, that means the accomplishment of R&D technical objectives—i.e., R&D technical productivity.

3.58 If the R&D work being done by your RDI is:

- Creative,
- Effective,
- Timely, and
- Economical,

then perhaps the organization of the RDI is optimum right now. If the R&D work being done is deficient in any of these ways, then perhaps the RDI's organization is one aspect of management which could be improved.

3.611 **Three Organization Designs:** There are many forms of organization; almost as many as there are RDIs. However, through them all it is possible to trace some common threads; and to label three general formats for organizing an RDI:

- Functional
- Project
- Matrix

3.612 In considering these three formats for organizing RDIs, remember that we are trying to organize in a manner which improves our chances of conducting successful R&D. That means we have to keep in mind the special character of R&D; like, non-routine projects; well-defined problems with totally unknown solutions; range from relatively short-term to seemingly interminable research activities; require the participation of diverse subject area specialists.

3.621 **Functional Organization:** The units of this organization are defined in terms of special skill areas (or "functions") like, agronomy, mechanical engineering, finance, or fisheries. This is a very common format for RDIs to start with, though they may not remain with this format long. Its primary characteristics are that:

What are the principal characteristics of a functional organization?

- It tends to work better with centralized structures in which the Director makes most decisions.
- The division of labour along functional lines leads to greater efficiencies than would be possible by the other formats.
- There is more professional affiliation since workers in the same specialty areas share the same department.
- Performance evaluation is likely to be more accurate since the departments are headed by specialists qualified in the respective functions.
- It tends to be a more formal, and less flexible format than either of the others.
- More difficult to coordinate, schedule and integrate activities between divisions because of functional differences, conflict and even competition between them.

What does division of labour mean?

What is professional affiliation? Why is it important to an RDI?

*What is performance evaluation?
What is evaluated?*

What form can inter-divisional competition take in your RDI?

3.622 RDI #2, drawn earlier, is a functional organization. Notice the separate units for R&D and administration; and within those, for engineering and administrative specialties. With this format we can only assume that the R&D projects grouped under each function, entail knowledge and skills in that specialty only. Thus Projects A, B, and C must be largely chemical engineering problems; D, E, and F—mechanical engineering; and G, H, and I—electrical engineering. But what happens if the RDI gets a project which requires knowledge from more than one of these areas; plus expertise in an area like metallurgy, which is not even represented in the organization. In which unit of the functional organization would such a project reside? That is the problem which gave rise to the project format for organizing RDIs.

Does your RDI ever have multidisciplinary projects?

How do you fit them into a functional organization?

3.631 **Project Organization:** This could read "programme organization." In this sense, programmes and projects have R&D technical objectives in common. With project organization, Organizational units are defined in terms of the

technical objectives of the RDI. And, since technical objectives coincide with R&D projects, or programmes, the units of this format end up being projects (or programmes—that is, collection of related projects). Many R&D programmes and projects are of limited duration and so when one is finished, this form of organization can change to adapt to new R&D technical objectives. The finished programme or project staff disbands, and is reorganized in new or extant R&D efforts.

What is the difference between an RDI which is organized on the basis of “functions”; and one which is organized on the basis of “projects”?

3.632 Quite obviously this format is far more flexible than the functional one. Other characteristics include:

- Each project unit is comprised of all the functional specialties needed to achieve the objectives of that unit.
- Focuses all the managers, resources and efforts of the RDI on the technical objectives of R&D projects.
- Provides more interaction and exchange among research workers from different disciplines.
- Requires more delegated management decision-making.

What are “functional specialties”?

What are “technical objectives”?

What kind of exchange?

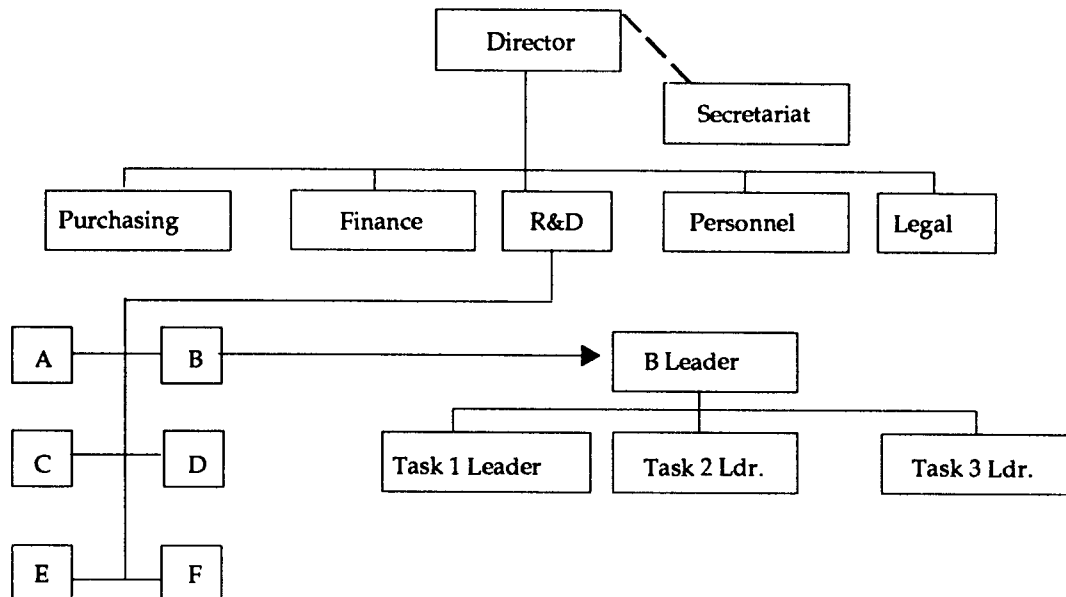
Why does it require more delegation?

3.633 At the top of the next page is an organization chart for RDI #2 if it were organized on a project basis. Compare it to the design for RDI #2 drawn earlier.

3.634 While the project format provides greater organizational flexibility than does the functional format, that is also its greatest weakness. The organization can become unstable with divisions organizing and disbanding as required by changes in the R&D project environment.

3.635 As an RDI becomes more project-oriented, greater flexibility results; whereas more stability (with the danger of becoming static) can be found in functional organizations. Therefore, a sound RDI needs both the pyramid hierarchy of a functional organization, and the capacity to organize project teams on both a temporary and

Figure 2. RDI #2 Organized on a Project Format



permanent basis. This is the purpose for which the matrix format was designed.

3.641 Matrix Organization: This format derives from a combination of the two ones previously discussed: functional and project organizations. It is a two-dimensional structure. One dimension comprises the functional activities that provide a pool of technical proficiencies needed to conduct R&D. The other dimension of the matrix comprises the R&D projects themselves.

3.642 The various functional units are arranged horizontally, while the programmes themselves are arranged vertically. The points where they intersect, or "nodes", characterize a particular functional unit's contribution to an R&D project. This contribution can be measured in personnel (person-hours) directly assigned to the project for a specified period of time—hence each node can, indeed should, be accounted in plans and budgets.

3.643 Necessary preconditions for successful matrix organizations are that:

- There must be a sufficiently large functional organization to serve as a reservoir of technical people to be assigned to projects.

*What is organizational flexibility?
When would it be desirable?*

*What does pyramid hierarchy mean?
Why is it associated with functional organization?*

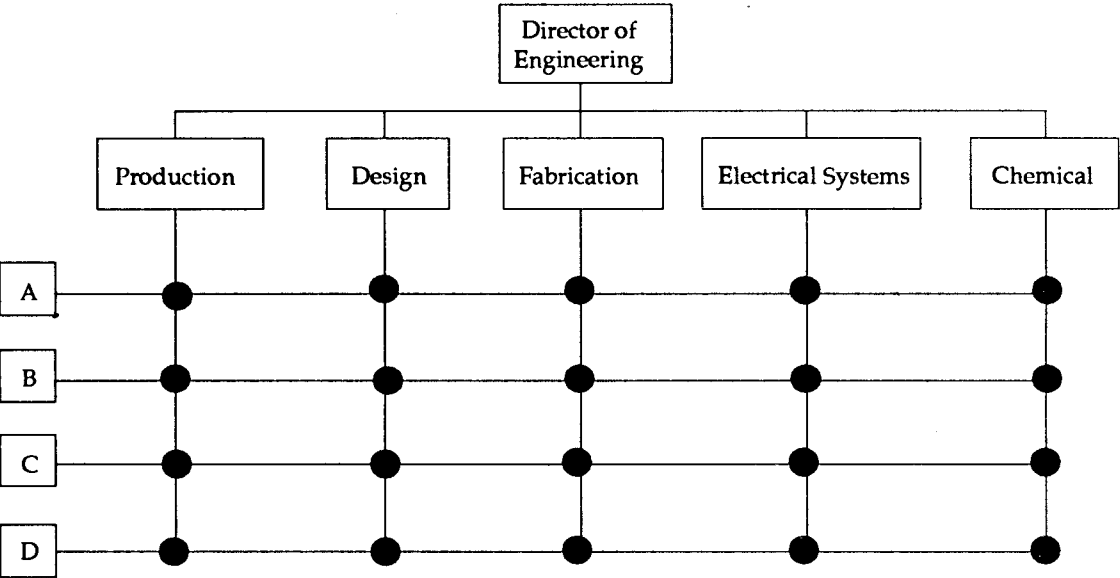
What are the characteristics of a matrix organization?

Do these preconditions apply to your RDI?

- The RDI must be large enough to support a number of projects.
- The overriding goal of the RDI must be R&D success and meeting of time limits, as opposed to economic efficiency.

Figure 3, below, shows the basic structure of a matrix organization applied in an RDI.

Figure 3. A Matrix Organization



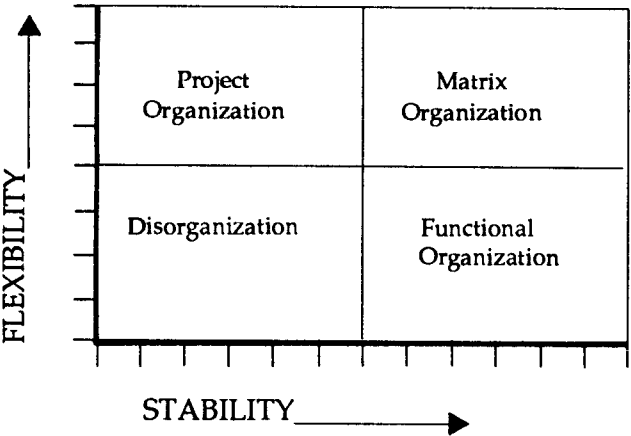
3.644 A matrix organization built around specific R&D projects offers the flexibility and at the same time orderly conduct which is needed for effective R&D management. A project leader is appointed and given the authority, responsibility and accountability for completing the project in accordance with time, cost, quality and quantity standards.

3.645 At the same time, the functional department heads share responsibilities for determining what has to be done and what resources will be needed to do it. They determine the broad details of how R&D will be conducted. But the project managers draw responsibility from top management to develop and maintain project plans, schedules and financial direction.

3.646 The functional department managers are responsible for controlling all resources in their functional areas; whereas, project managers are responsible for resource utilization on a research programme, or project basis. Conflicts are negotiated between them, sometimes with the assistance of higher management.

3.647 Figure 4 shows a graphical representation of the relationships between these three types of organization, and the characteristics of organizational flexibility and stability.

Figure 4. Relationships Between Type of Organization and RDI Stability and Flexibility

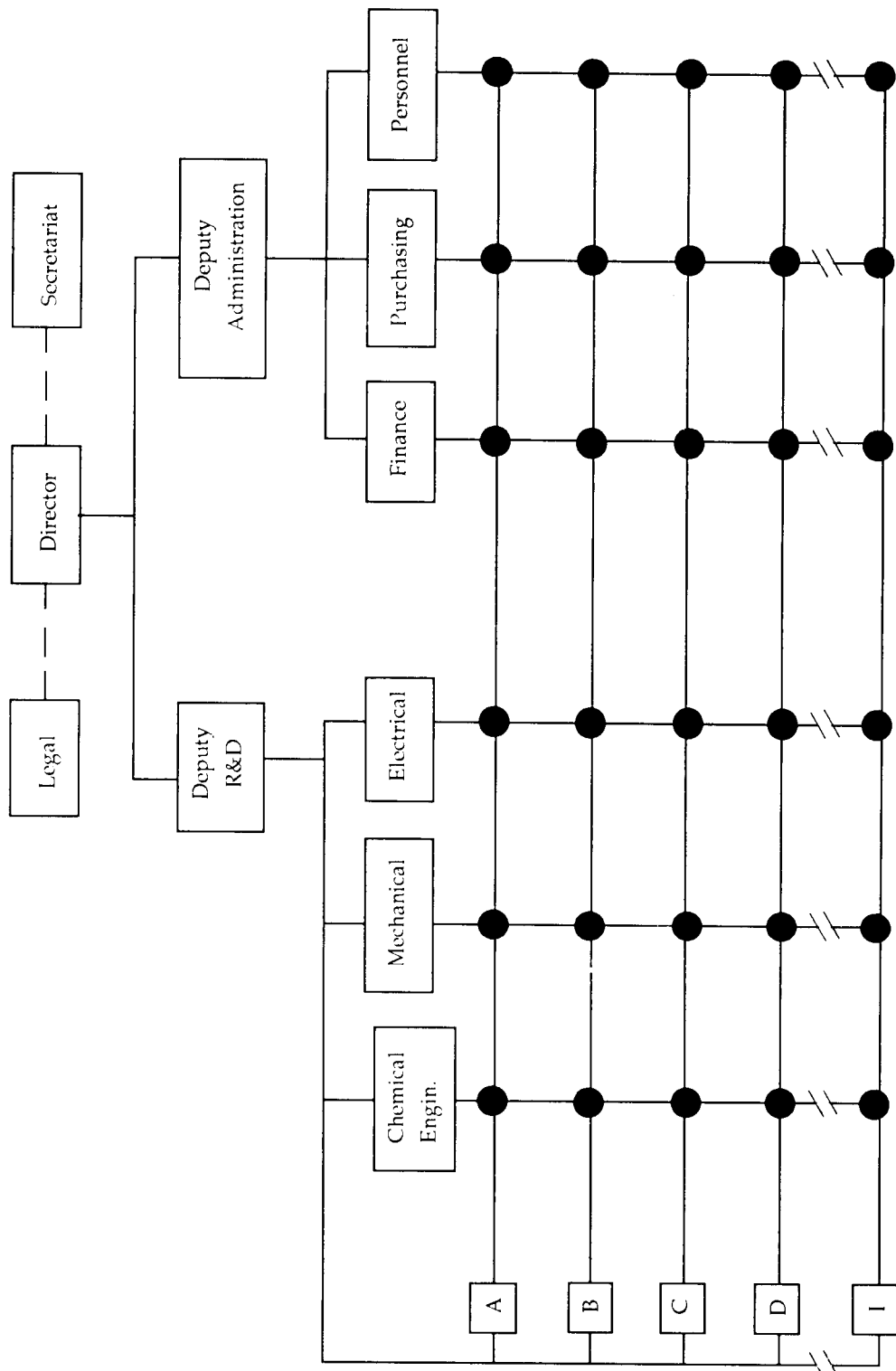


Exercise 3: RDI #2 as a Matrix Organization

In the space that remains on this page, redraw RDI #2 as a matrix organization. DO NOT LOOK AT THE NEXT PAGE until you are ready to see how we would redraw it

(Exercise 3: Continued)

Our Rendering of RDI #2 as a Matrix Organization



3.648 The matrix organization is designed to capitalize on the advantages of both the functional and project structures. The coordination necessary for programme completion is provided through the project leaders and their research teams; while the technical support needed for R&D is provided through functional department heads.

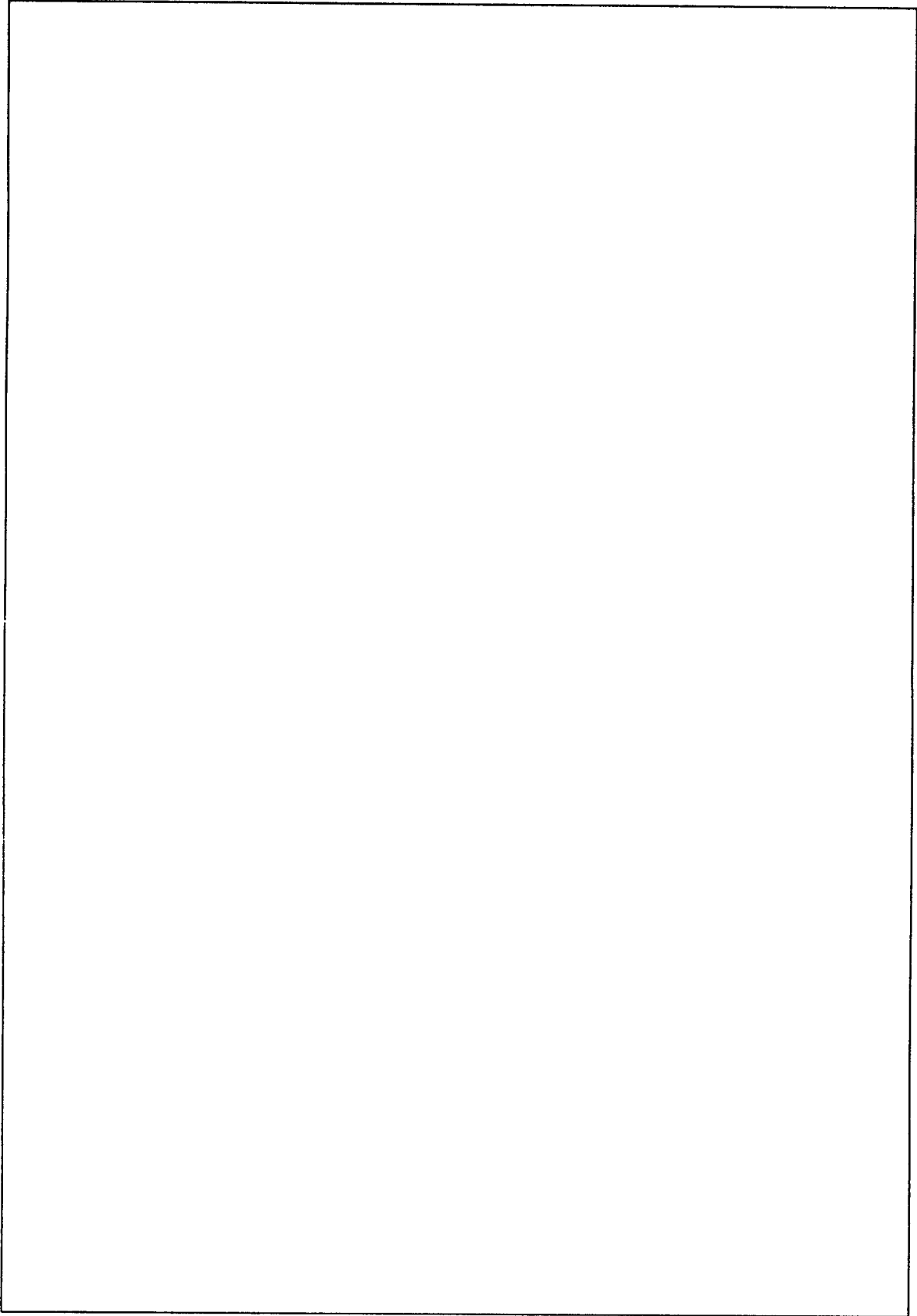
3.649 The matrix organization is intended to provide maximum democracy, cooperation and collaboration (particularly on interdisciplinary projects or programmes) and staff satisfaction. But it is a form of organization which requires a management style of maximum delegated responsibility and open communications. It is not very common in developing countries. More traditional hierarchical forms of organization are more common.

Exercise 4: Analysis and Reorganization of Your RDI

Team with one other workshop participant, from a different RDI, for this exercise. Consult and help each other throughout the exercise.

1. Share with each other your RDI organization charts (drawn earlier).
 2. Discuss with each other whether the two RDIs are organized on a functional, project, matrix, or some other format.
 3. How do you know; what are the signs? List them for each RDI.
 4. On a separate note paper, collaborate with your partner in redesigning both RDI organization charts. Only this time, draw them using the matrix format.
 5. When you have the new matrix design just right, make a final drawing of it on the next page.
-

(Your RDI structured as a matrix organization.)

A large, empty rectangular box with a thin black border, intended for a student to draw a matrix organization structure. The box occupies the majority of the page below the text prompt.

3.71 Human Relations: A lot of emphasis has been placed in this chapter on the structure of an RDI. But it is important to close the discussion of organization with the observation that no structure, in and of itself, guarantees the success of an RDI. In the end, the success of an RDI is dependent on the quality of human relations among all personnel who work there.

3.72 Now, structure can help or hinder human relations. In fact it is conceivable that in two separate RDIs, the same structure could have the opposite effect on human relations. It depends on the skills and attitudes of the people who are organized. Do they want to share responsibility? Do they want open communications? Do they want close oversight on their decisions? Do they want to learn from their own mistakes?

3.73 We could discuss human relations in some detail. That will be done in another manual on R&D personnel management. However, suffice it here to say that a number of techniques can be applied to improve human relations in any RDI—no matter how it is structured. Some of them are:

- Sympathy for problems of individual workers;
- Openness and accessibility for communication and discussion with any worker;
- Assessment of issues based on actual facts rather than preconceived ideas; and,
- Use of “management committees” to advise directors and department heads on all matters of policy, resources and problems.

What kinds of human relations skills are most productive in any type of RDI organization?

To what extent do they exist in your RDI?

How do project, functional and matrix forms of organization influence the following attitudes:

- openness
- understanding
- fairness
- sharing

What other, non-organizational, factors can influence these attitudes?

ORGANIZING: Selected readings for more study

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*MANAGEMENT MANUAL FOR PRODUCTIVE R&D:
R&D STRATEGIC AND PROJECT PLANNING AND BUDGETING*

CHAPTER IV
PLANNING

PLANNING

Training Objectives

By the end of this chapter, participants will be able to:

1. Define planning.
 2. Distinguish between strategic and operational levels of planning.
 3. Discuss the relative strengths and weaknesses of topdown, and bottom-up planning for R&D management.
 4. Develop a model showing the relationship of R&D strategic and project planning, to national development planning.
 5. Identify and explain six elements of an R&D plan.
 6. Describe five steps in a standard planning process.
 7. Determine the tasks inherent in an R&D project and develop a Work Breakdown Schedule.
 8. Plan a project via Bar Chart and Networking.
 9. Calculate critical path, slack time, and expected dates of completion for a hypothetical R&D project.
 10. Explain the advantages and disadvantages of Task Lists, Bar Charts, Deliverables Charts, and three networking techniques, for R&D planning.
 11. Develop and apply a scoring and ranking form for R&D project selection.
 12. Explain the role of planning in R&D management.
-

PLANNING

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This material should be covered in about three sessions, of fairly equal duration. Exercises at the end of each part can usefully serve as between-session "homework."

CHAPTER IV

PLANNING

The uncertainty of the outcome of R&D does not mitigate the importance of planning. Instead, it reinforces the value of any exercises which can improve the probability that R&D will accomplish desired ends—within the limits of human capability, time, and financial and material resources.

1. Role of Planning in R&D

4.111 Introduction: R&D technical performance, as well as budgeting and cost control, depend on sound planning. The hours spent planning ahead will payoff many times over as the R&D work schedule unfolds.

4.112 But, in the case of R&D management, planning should be regarded as “drafts” of the way things are expected to go. If they do not go that way, the plans need to be altered—so that people’s expectations are altered. The goals set in R&D plans should be considered key decision areas, rather than key results—as indicators of technical performance, rather than standards against which the success of technical performance is judged.

Should plans be considered “final” determinations of how a project or programme will proceed? Why, or why not?

4.121 Definition: Planning is the process of making decisions about what is to be done; why;

What is planning? What do plans tell us? Why do we make plans?

for whom; how; by whom; with what resources; and when? Basically, it is the attempt to predict, before any work is expended, exactly what will be known after the work is done: the technical results; their cost; the methods of achieving them; and the resources required to achieve them.

4.122(a) Planning is a particularly difficult task in an RDI because the very nature of the work is, by definition, highly uncertain. Therefore, R&D plans talk not about the expected outcomes of R&D, but rather, the desired characteristics of those outcomes. Actually, planning in an RDI has different qualities for different kinds of R&D projects:

- Basic research
- Applied research
- Adaptive research
- Development

4.122(b) **Planning in Basic Research:** Four aspects of basic research make planning precision very difficult to achieve:

1. Difficulty of predicting the product or process outcomes of basic research.
2. Difficulty of predicting the time required to complete the research.
3. High probability that discoveries along the way will change the direction or emphasis of research.
4. Researchers' special needs for freedom to pursue any phase of the research, and to spend some time and resources on their own special interests.

Why is planning for R&D so difficult?

*Which is easier to plan—basic or applied research?
Why?*

4.122(c) As a consequence, the parameters which come into play for planning basic research, more often relate to the desired net effect of research results; the amount of researcher time available, instead of the amount required; and the amount of financial and other resources available, as opposed to the amounts needed.

What proportion of the work conducted in your RDI is basic research?

4.122(d) No one can minimize the value of basic research. However, in terms of personnel and money, it is far less prevalent in RDIs than are applied research and development work. It is most

often regarded as the domain of universities and endowed foundations. Thus while planning of basic research is difficult, the demand for it among RDIs is small.

4.122(e) Planning in Applied Research:

Applied research can be planned with more precision than can basic research. Here as with development, there is the "project" which can be titled and described. It usually starts with examination of the pertinent state-of-the-art; then it proceeds to trials or experiments. Regardless, the steps in the project may be accurately predicted and ordered.

What are the major parts of an R&D project plan?

4.122(f) Lists of personnel and other resources, tasks and the time required to complete them, may be generated in advance of any research work. And these are the building blocks of any good research plan.

4.122(g) Planning in Adaptive Research:

Adaptive research is that work which is necessary to "adapt" an imported (or otherwise "foreign") technology to the idiosyncracies of the environment and needs of the end users. It requires careful analysis of the characteristics of the technology and the applications for which it is designed. But, it also requires equally detailed analysis of the local uses to which the technology is to be put.

What is the difference between applied and adaptive research?

How is planning similar for both of them?

4.122(h) Both of these adaptive research processes are readily planned. There is far less uncertainty in planning for adaptive research because the subject technology has already been developed.

4.122(i) Planning in Development Work:

Planning can be even more exact in development work, than it is in applied research. This is because:

Why do we plan R&D?

1. The results can be specified clearly.
2. Amount of time can be estimated.
3. The development tasks can be specified.

*How is an R&D project plan used?
By whom?*

4.122(j) Since they are easier to plan, development tasks are also easier to control. And, after all, **control is the name of the planning game. We plan our R&D so that we may obtain the results needed, within the resource constraints given to us.** Planning, therefore, is the most basic of R&D project management tools.

4.131 **RDI Planning:** Planning is also an essential tool for RDI, as well as project management. The difference is that applied to projects, planning helps assure the achievement of technical objectives within cost and other resource constraints. Applied to the whole RDI, planning is vital for determining:

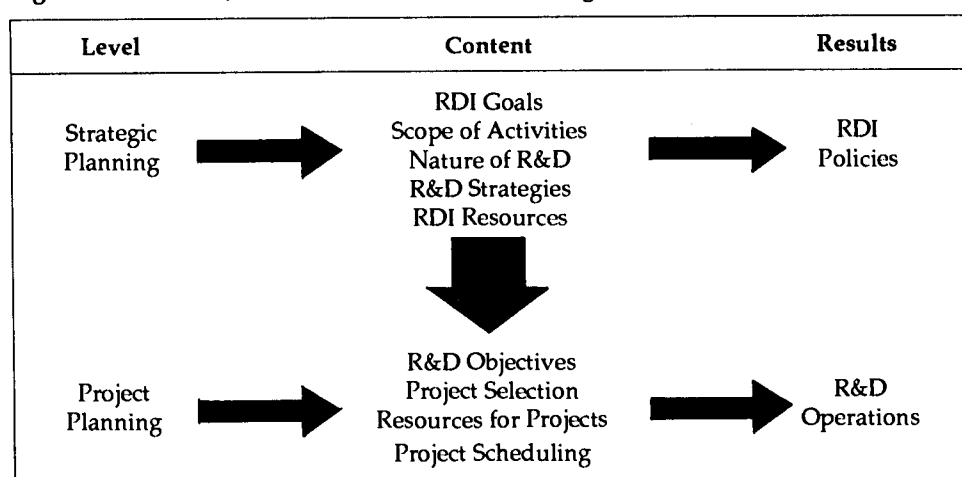
What is an RDI strategic plan?

How does it differ from an R&D project plan?

- Long range goals of the RDI
- Priority areas for R&D work
- R&D strategies to be used
- Personnel, money and other resource requirements.

4.132 This application is called “strategic planning,” to differentiate it from “project planning.” RDI strategic planning leads to policies which govern the entire effort of the RDI. **Figure 1** shows the relationship between strategic and project planning:

Figure 1. The Level, Content and Results of Planning in an RDI



4.133 It is important to note in this Figure how strategic and project planning relate to each other. Usually an RDI gets started when someone in the government realizes that some kind of R&D

would enhance development in the country. But it is not a short leap from that idea to an effective research project. Usually some kind of organization must be formed to oversee the research. Buildings and other facilities must be developed. Equipment and supplies must be obtained. Various kinds of personnel must be located, recruited and hired. And, all of these arrangements require financial commitments from government. Obtaining those commitments from a ministry, a legislative body, or some other group usually requires assurances that all these requirements are justified, and that none of these resources will be squandered or mismanaged. That is the role of strategic planning.

How do strategic and project planning relate to each other?

4.14 Strategic Planning specifies the purposes and goals of R&D; the range of economic and development problems on which R&D is proposed to focus; the extent and limits of government resources which are to be expended on the venture; and the basic R&D approaches which are to be used. The results of strategic planning lead to a collection of statements called "RDI Policies." They provide the mandate, specification of resources, and techniques for managing them, on behalf of the proposed R&D.

*Why do we do strategic planning; what is its purpose?
Who does it in your RDI?*

4.151 Role of Planning: The role of planning at both levels (strategic and project) is similar. At the strategic level, planners focus on the expected results of R&D. This is one of the most important opportunities to relate R&D to national development goals and the economic, social, political, cultural and strategic needs of the country. **This step is too often overlooked. As a result, R&D frequently remains divorced from a full understanding of its ultimate purpose and intent particularly by researchers who can get caught up in the research issues and lose sight of their role in national development.**

How do R&D plans relate to national development plans?

*Do your RDI plans relate to your country's national development plan?
Give us some specific examples.*

4.152 Where can you find a statement about the RDI goals; and the relationship of R&D to national development? We recommend looking in a couple of places:

- National Development Plan
- Parent Organization's Charter
- RDI Charter or Other Mandate

4.153 The National Development Plan is nothing if it does not state the national development goals of the country. Further, it relates how each government agency and programme fits into a concerted effort to achieve those goals over a limited period of time; and with limited resources.

Does your national development plan say anything about the role of R&D in national development? What; be specific?

4.154 If your RDI is an arm of a government ministry (like the Ministry of Industry), or of a private association (like the Tobacco Growers' Association), or a branch of some other agency (like the Department of the Army), then chances are good that you can find RDI goals in the charter or other mandate document of that parent organization.

4.156 Then of course, your RDI's own charter or other mandate document should also restate the goals of the organization.

Does your RDI have a charter? What is the "enabling document" for your RDI?

4.157 At the project level, planning is also used to focus researchers on the desired outcomes of R&D projects. Usually, project objectives are stated in technical or economic terms. But that notwithstanding, the relationship between RDI goals and R&D project objectives should be clear to the knowledgeable observer. We should be able to see how achievement of project objectives will further fulfillment of RDI goals. Where can you find a statement of R&D project objectives? Try the project plan. Project technical objectives should be one of the earliest things to appear in this document.

What language in your RDI's enabling document relates directly to the country's national development plan?

4.158 Resources too, are vital elements of planning at both levels. At the project level they should be very detailed. The project plan should show the facilities, equipment, raw materials, money and personnel needed; per research task, and per unit of time. Such precision is required in order to control the expenditure of all these vital and limited resources. At the strategic level the same principle applies. Look in the National Development Plan and see if it specifies the rate of government expenditure for R&D, in any sector. Some plans even specify total financial investment in R&D, per RDI, for the period of time covered by the National Development Plan. Figure 2 provides

What language in R&D project plans relates directly to the enabling language for the RDI? Be specific!

Case 1: STRATEGIC GOALS IN A NATIONAL DEVELOPMENT PLAN

The National Development Plan is a good place to look for evidence of strategic planning for research and development. A four-year plan published by a country in Eastern Africa evidenced strategic support for science and technology in general; and, for various RDI's in particular. Here is part of what they said about science and technology:

an example taken from one National Development Plan.

4.159 Strategic plans for R&D, an RDI, or S&T may appear in two formats, within a National Development Plan. There may be a section of the Plan devoted to Science and Technology. In this case, the section would probably devote language to each economic sector in which the government planned a role for R&D. Or, such strategic plans may be incorporated in the sector-specific sections of the Plan. For example, the section on agriculture may have some language on agricultural R&D.

4.161 **Strategic and Project Goals:** It is important to notice the differences between R&D goals as stated in the strategic planning documents, and R&D technical objectives, as stated in specific R&D project plans. Basically, strategic planning goals are more general; they specify a broad area of research activity. They relate scientific and technical investigations to sectors of the economy.

In the coming ...period, efforts will be intensified to undertake research and developmemnt activities in all major sectors of the economy... Efforts will be directed to the development of appropriate technologies by assisting in situations including schools which indicate an ability for innovation, improvisation, and investiveness.

They went on to specify some science and technology goals like:

- i. to encourage both the public and private sectors to participate more in research activities, particularly ...using local resources;*
- ii. to build ... information centres for dissemination of science and technology information to the nation...;*
- iii. to establish a patenting system ...; and ,*
- iv. to encourage use of local consultancies in the design of development projects with technological inputs.*

Figure 2. Annual Allocations (Recurring) for Six RDIs (x \$1000 U.S.)

Institute	1984	1985	1986	1987	1988
Centre for Science and Technology	13*	15 (15%)	16 (7%)	17 (6%)	18 (6%)
Agricultural Research Institute	154	192 (25)	201 (5)	204 (1)	222 (9)
Trypanosomiasis Research Institute	74	93 (27)	99 (6)	103 (4)	111 (8)
Medical Research Institute	22	26 (18)	20 (-23)	28 (40)	30 (7)
Industrial Research Institute	26	32 (23)	33 (3)	35 (6)	36 (3)
Fisheries Research Institute	46	57 (24)	55 (-4)	57 (4)	58 (2)
TOTAL	335	415 (24%)	424 (2%)	444 (5%)	475 (7%)

*The numbers in parentheses in the other columns show the percentage of increase, or decrease, in annual allocation, from the previous year.

4.162 Project technical objectives, on the other hand, are much more specific. They detail the technical results which are desired from a particular line of investigation. Usually they are more technical sounding; it usually requires some foundation in the relevant technology to even fully understand these planning objectives. Case 2, on the right side of this page, describes the objectives, of a project visited at a specific crop research institute in Eastern Africa. Notice how you would have to be a specialist in this particular field to even know what the objectives mean. Can you guess what crop is researched by this RDI?

4.171 **Value of Planning:** Why is planning done at either level—strategic or project? What value does it have for either the RDI manager, or the researcher? The answer lies in the nature of organizations. Usually researchers are embedded in an RDI composed of many (perhaps hundreds) people, engaged in a wide variety of activities, spending large volumes of diverse resources, and so on. How is it possible for all these people to remain aware, interested, and supportive of one particular R&D project? What keeps them from becoming distracted by all the other requirements of a large organization? And what keeps such distraction from interrupting the search for R&D results? The answer is planning.

4.172 The same is true at the strategic level. An RDI is embedded in a large government infrastructure. How is it possible for such a large organization to provide sufficient resources, programme awareness, priority attention and support for the efforts of an RDI? Planning makes this possible. It accomplishes several things:

1. Provides clear directions for the RDI (or project) by specifying its reason for existence, and expected results;
2. Establishes clear understanding of the resources required and commits them for the objectives to be achieved;
3. Explains scheduling limitations and opportunities which impinge on the R&D effort;
4. Helps management, at both levels, anticipate R&D problems and ob-

Case 1: Continued

The plan also specified goals for RDIs in particular sectors. For example, for the agricultural research institute, it specified goals in animal production research:

- i. the role of agro and industrial by-products in feeding will be studied...;*
- ii. studies will be intensified to determine factors that limit milk production in systems based on napier grass; and,*
- iii. to identify suitable breeds for milk and beef production over and above the subsistence requirements in the semi-arid areas.*

Such specificity was also offered in a variety of other sectors.

Case 2: OBJECTIVES IN AN RDI PROJECT OUTLINE

An institute which provides R&D to enhance the production of a cash crop for export, recently adopted a project planning format which places priority on careful specification of R&D objectives.

Their new Project Outline requires very succinct statements of the project title, purpose and objectives before anything else is said. Here are these three components taken from a real project of theirs.

Title: *Evaluation of Different Rates of Selected Copper Formulations for Integrated Control of BBC and CBD.*

Purpose: *This project is a followup of the work carried out during 1980–81. It will be done on the same trial site*

- stacles;
5. Reduces the need for "crisis management"; and,
 6. Provides a basis for monitoring, controlling and evaluating the accomplishment of goals and objectives.

4.173 One qualification should be added, at this point. Planning accomplishes all these if it is done well and frequently; and if it is taken seriously.

as in 1981; to enable the assessment of cumulative and residual effects of selected copper formulations, namely Kocide 101 (0.7%) and Procida Bordeaux mixture (1.0%) with respect to BBC, CBD control and yield.

Objectives: (1) To evaluate the performance of full rates, and half rates of Kocide 101 and Procida Bordeaux mixture in the control of BBC and CBD, and in yield response. (2) To relate the level of BBC control to the epidemiological factors with particular reference to the distribution of leaf surface bacterial inoculum, the number of infection targets, and weather conditions.

RESULTS OF PLANNING

1. Direction
2. Resources
3. Schedules
4. Predicatability
5. Control
6. Problem solving
7. Evaluation

So, why do we plan R&D?

Exercise 1: Analysis of Your Own Strategic and Project Plans

Let us apply what we have been discussing to your own strategic and project plans. Take a look at your country's National Development Plan; find any mention of S&T, R&D or RDIs. Answer these questions:

1. How is this information organized in the Plan?
2. Does it cover all RDIs; does it establish broad goals for R&D; does it prioritize economic sectors; does it provide parameters on resources devoted to R&D?
3. Does it provide for changes in either goals or resources for R&D over a period of years?
4. How could the strategic plan for R&D be improved?

Next, take a look at one plan (or proposal) for an R&D project from your RDI. Answer these questions about it:

1. Does it include statements of objectives for the research?
2. Are the objectives clear, i.e., is it possible for a knowledgeable reader to know exactly what is expected from the results of the R&D?
3. Do the objectives sufficiently quantify the expected outcomes of R&D, so that it would be possible to establish measurable criteria for the success of the R&D?
4. How could these project objectives be improved?

Write a few paragraphs on your answers to both of these sets of questions. Make sure your name is on your paper; give it to your instructor(s) so that they may review your comments before the next workshop session.

[Instructor(s): Read all these quickly; trying to assess the participants' general comprehension of the concepts of strategic and project planning. Be alert for particularly insightful papers which you think would stimulate the other participants. Ask the author if you may share their comments with the others during the next session. If so, be sure to tell the participants what you think is particularly good about this paper.

As you read the individual papers, make comments to the authors, in the margins, when you think you can further their understanding of strategic and project planning. Look for any papers which indicate the authors would benefit from direct consultation with you. If you detect some generalized confusion, be sure to address it in the next session.

After reading all the papers, be sure to provide all the participants with generalized feedback. Then return the papers and encourage them to incorporate them in their workshop notes as guidelines in planning which they may want to investigate when they return to their own RDIs.]

4.18 Term of Plans: R&D plans can be developed for any amount of time. In truth, they should be done for the long-, and short-term. At the RDI level, it would be a good idea to know the general direction of R&D in the long term (5 years). At the project level, it is essential to plan for the duration of the project, however long that might be. Further, each research unit in the RDI, and the RDI as a whole should have a plan which specifies objectives, activities, expected results, and resource requirements for a period corresponding to the government's financial year.

What is the difference between strategic and project plans, in terms of their effective period?

4.191(a) Planners: Who does the planning in an RDI? Is it the director, a deputy director, a staff arm of the director, the financial controller, a planning division, the heads of functional departments, project leaders, project workers, or someone else?

4.191(b) The answer to this question depends, in part, on the answer to another one: who has the most complete knowledge and understanding of the purposes and processes of R&D being planned? It is not a question of authority to make planning decisions. It is a question of having enough knowledge and information to develop realistic and meaningful plans.

Who does the planning in your RDI?

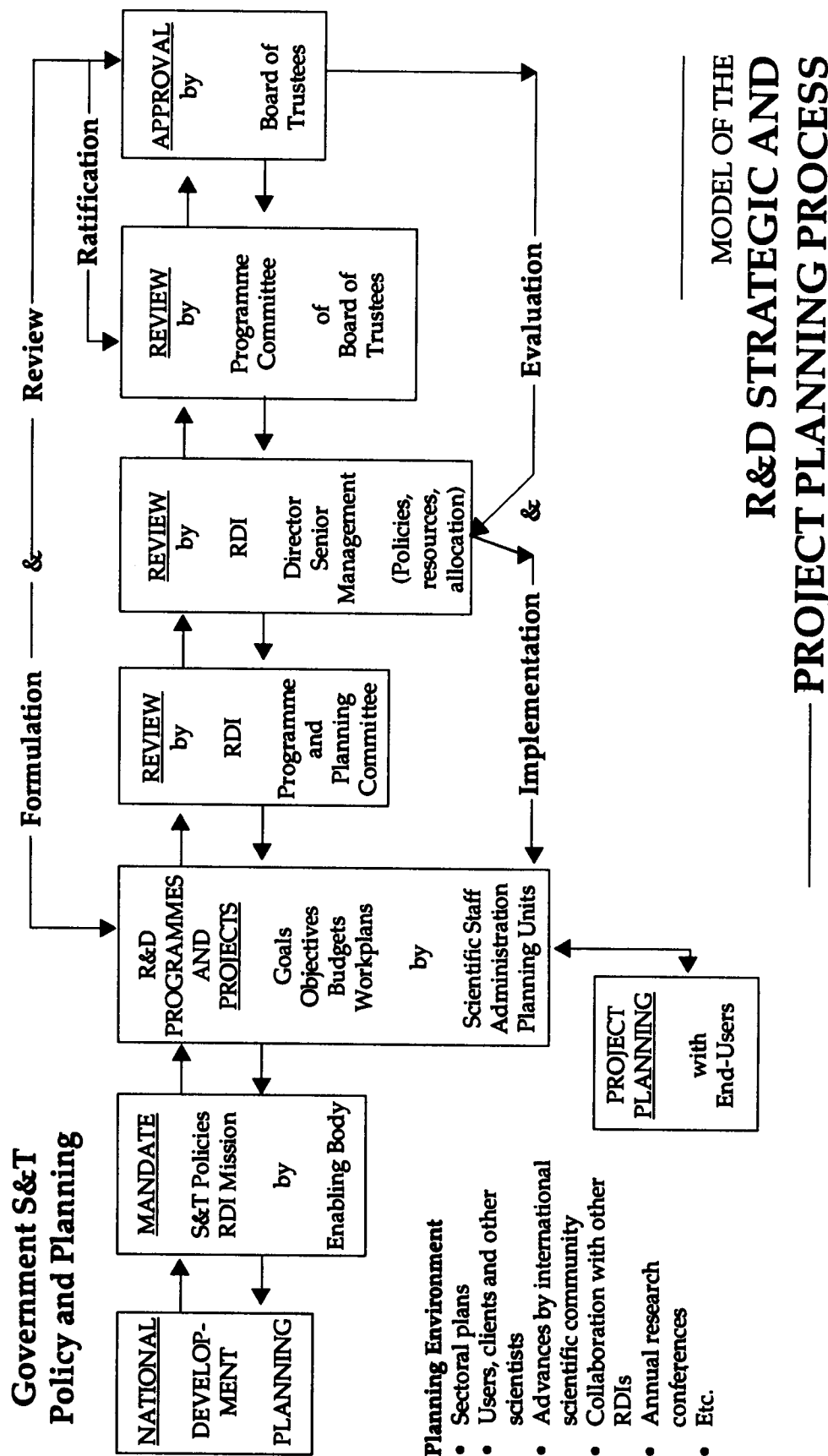
What is their level in the management hierarchy?

4.191(c) What kinds of knowledge and information are needed, in order to do good R&D planning? Well obviously, knowledge of the proposed technology and R&D methods is critical. That suggests that researchers have a hand in the planning process. But, knowledge of the development problems to be solved is also vital. Knowledge of the character and capabilities of technology's end-users is vital. Many times, the most knowledgeable people on this subject are the end-users themselves. This suggests that they also have a hand in the R&D planning process.

Can researchers really do planning—which is a management tool?

4.192(a) Planning Model: While considering who "the planners" are, it might be useful to depict a comprehensive model of the R&D planning process. The diagram on the next page summarizes all we have said about R&D planning, so far. It is a model which originated with an international RDI located in Eastern Africa. It was

RDI Strategic and Project Planning



originally conceived by that RDI's Senior Planning Officer. But it was also enhanced by the efforts of R&D management and public administration experts from the region.

4.192(b) In the model it is important to notice that R&D planning has five major elements:

- National development planning
- RDI strategic planning
- R&D programme and project planning
- R&D end-users needs
- Planning environment

4.192(c) There is a logic inherent in the elements of R&D planning. For example, national development planning is based on an analysis of the development needs of R&D beneficiaries. And hopefully, an RDI's strategic planning coincides with national development priorities. Finally, R&D project planning is designed to achieve RDI strategic goals.

4.192(d) The "planning environment" relates to planning activities throughout the government infrastructure; technical advances in the country and in the international scientific community; and economic and other resource opportunities and constraints on R&D.

4.192(e) We presented this model during a discussion of who is responsible for planning R&D. From a look at the model, what do you think the answer is to that question? Doesn't it appear obvious that quite a lot of people, at various positions in government, RDIs, R&D project staffs, and even the public, are involved in R&D planning?

Compare this model with the one on page 98. What are the similarities and differences?

4.192(f) Well consider another question. Which way does the R&D planning process flow? From the R&D end-users up to the RDI Board of Directors and even unto national ministry level officials ("bottom-up" planning)? Or, from national-level development planners, down through RDI directors and eventually to the R&D beneficiaries ("top-down" planning)? Look at the model on the previous page. Which way do you think R&D planning flows?

4.192(g) One thing should be obvious. The question is far simpler than the answer. This is because the planning process is not unidirectional. Planners at all levels cycle planning in an iterative process which over the whole course flows in both directions. Nonetheless, let us take a moment to consider the relative merits and demerits of top-down and bottom-up planning processes.

4.193(a) **Top-down, Bottom-up:** If the Director, or some other senior manager, does the planning and simply informs lower divisions of the RDI how they must adhere to it, then we have an example of top-down planning. It means that the planning is a function jealously guarded by top management, and levied as a *fait accompli* on units farther down in the organization.

4.193(b) In contrast, we can conceive of the RDI in which project directors are asked to complete their plans; pass them up to division heads who aggregate them into larger plans; and then pass them up to top management to represent the total RDI plan. That is an example of bottom-up planning. Both approaches have their merits and demerits.

4.193(c) Top-down planning is desirable because it yields the greatest amount of control on the planning process—hence on the programme directions of the RDI. That is one of the reasons why some RDI directors protect this function so diligently.

4.194(d) On the other hand, top-down planning has demerits also. It usually alienates RDI staff at all lower levels because they feel that top management does not respect their opinions; and that they have no control on the directions of their own work. This can create severe morale problems.

4.194(e) But top-down planning also suffers because few RDI directors are sufficiently knowledgeable about all R&D in their institutes to develop quality plans. (A possible exception to both of these demerits to top-down planning would be in the case of new, and small RDIs in which the director does have sufficient knowledge and enjoys the confidence of all RDI staff.)

Is planning in an RDI a unidirectional process? Why, or why not?

*How would you characterize planning in your RDI; top-down, bottom-up, or both?
Explain!*

What kinds of morale problems can result from top-down planning?

Who has the most accurate and detailed information to offer R&D planning in your RDI; the RDI director, or R&D project leaders?

What is the role of your RDI Director in planning?

What is the role of your RDI head of administration in planning?

What is the role of R&D project leaders, in your RDI, where planning is concerned?

4.194(f) The bottom-up planning approach is desirable because it rewards staff for knowing about their own work and its relationship to the RDI mission. Further, the resulting plan is sure to incorporate the quality of information needed to make sound resource and scheduling decisions.

What is your role in planning as it is currently done in your RDI?

4.194(g) However, the bottom-up approach suffers for a couple reasons. Staff in lower divisions of the RDI lack sufficient perspective to plan on behalf of the entire institute. Managers at different levels in the RDI have differing points of view—all of which require coordination in any bottom-up planning exercise. Finally, top management has insufficient opportunity to influence the directions of the RDI.

4.194(h) In contrast to either of these approaches, we recommend one which combines the merits of both—a **top-down/bottom-up** planning approach. It is an effort led by top management; but it incorporates the planning efforts of all lower levels of management as well.

4.195(a) **One Planner:** Should one person, at any level in the RDI, be solely responsible for planning R&D? It has the advantage of simplifying the planning process. But it is disadvantageous in almost all other respects. One of the most significant drawbacks is that no single individual can have sufficient information and knowledge to develop a practical and meaningful plan.

*Do you agree with this generalization
Why, or why not?*

4.195(b) This approach, unfortunately, is frequently tried in RDIs. It is usually implemented by a director who lacks confidence in any subordinate managers; and that is the message which all subordinate managers get first.

4.196(a) **Planning Unit:** What about a planning unit in the structure of the RDI? Usually such a unit is a staff arm of the director, or the financial controller's office.

4.196(b) This approach has the advantage of fulltime people thinking about planning. Further, if they are attached to the financial controller, then

the planners have that all important financial perspective. But it has the disadvantages of being, basically, a topdown process. It leads to alienation of the staff. Further, it frequently shows gaps in knowledge of research processes and technical requirements.

4.197(a) **Planning Committee:** What about an *ad hoc* committee organized for the expressed purpose of leading the planning exercise? A lot depends on how this committee is composed. It can have the advantages of the planning unit described earlier. However, it too can lead to alienation of RDI staff, unless it implements a participative planning process.

Has your RDI ever used a planning committee? If yes:

- *Who was on it?*
- *How well did they do?*
- *How were they received by RDI personnel?*

4.197(b) This approach works best when the committee is supported by subcommittees organized at the division level. In effect then, planning becomes an institute-wide activity, coordinated by a central committee. That can be quite effective. For that matter, such division subcommittees can even make the more centralized planning unit, and one person approaches more effective.

4.198(a) **Planning and Organization:** Perhaps you can begin to see that the approach to planning in an RDI is related to the type of organization. If, for example, the RDI is characterized by a highly centralized management structure, then probably planning will take on a top-down character—perhaps with one person, or an *ad hoc* committee doing it.

What planning approach seems attractive for your RDI:

- *One person?*
- *Planning unit?*
- *Planning committee?*
- *Combination of these?*
- *Other (what)?*

4.198(b) In a functional organization, the main characters involved in the planning will probably be functional division heads and top management. Where is the influence of the researcher? Similarly, in a project oriented structure, the research leaders would have a significant role and we might become concerned about a role for functional specialists.

Explain your answer!

4.198(c) A matrix structure would stimulate more balanced involvement of functional specialists and project personnel.

4.198(d) Project staff have to be considered important since it is primarily their efforts which lead to the success or failure of the RDI to achieve its strategic goals.

Exercise 2: Designing a Planning Structure

Divide into small discussion groups of three participants from different RDIs. Each participant should take their workshop book to the discussion. Each discussion group should allow five minutes per person to discuss the optimum planning structure for the RDI organization drawn by the participants in their workshop book. All three discussants should collaborate on the design of the optimum planning structure, for each RDI. For the sake of this discussion, assume that the resulting structure will have to develop the annual programme plan for the RDI. Therefore it will be important to build-in project level perspectives. The discussion groups must organize planning so that it is most effective with the type of structure in the RDI. Therefore, for each participant they should discuss:

1. What kind of organization structure is represented by the RDI?
2. Is authority centralized or decentralized?
3. How much role and responsibility do R&D project directors have in influencing the direction of the RDI?
4. How large and complex is the RDI organization?
5. How difficult will be the task of obtaining and coordinating planning information from all the pertinent divisions in the organization?
6. From which unit in the organization would it be best to draw leadership for the planning activity; why?
7. Which units of the organization have the most, critical planning skills to offer the exercise?
8. What other units are vital to the planning exercise?
9. What units could be largely ignored in the planning exercise?
10. What would be the most efficient structure for planning?

It is the responsibility of each group to help the participant design the planning structure with which they are happiest. In other words, the group works at it until the participant is satisfied with the results. Then the discussant makes notes recording the resulting structure.

[Instructor(s): Allow 20–30 minutes for this exercise. During the discussions, circulate among the groups and help where necessary to expedite useful discussions.

Note particularly creative or instructive discussions—perhaps one or two—and select them for reporting to the whole group (in plenary) after the conclusion of the discussion period.]

2. Tools for R&D Planning

4.21 **Introduction:** In the above material we introduced the concept of planning and explained its role in national development planning, RDI strategic planning, and R&D project or programme planning. Throughout the rest of this discussion, we will be talking about tools of planning and how they are applied. But it is important to note that they may be applied at any level—strategic, programme or project. For the sake of consistency in our explanation, we will use an example of an R&D project. But the principles of planning depicted therein also apply to programme and, or, strategic planning.

4.221(a) **Elements of a Plan:** Whether it is an R&D project plan, an RDI annual programme plan, or an S&T policy statement in a National Development Plan, all R&D plans have more or less the same components:

<ul style="list-style-type: none">• Goals and/or objectives• Activities and/or tasks• Methods• Schedules• Resources needed• Management techniques	Do the plans of your RDI have all these parts? Put an X in the right box for each one!	No	Yes
}	}	<input type="checkbox"/>	<input type="checkbox"/>
		<input type="checkbox"/>	<input type="checkbox"/>
		<input type="checkbox"/>	<input type="checkbox"/>
		<input type="checkbox"/>	<input type="checkbox"/>
		<input type="checkbox"/>	<input type="checkbox"/>
		<input type="checkbox"/>	<input type="checkbox"/>

4.221(b) Ultimately we will be focusing on financial resources, in this workshop. However, it is important to place them in the context of other components of the R&D plan.

4.222 We discussed **goals and objectives** earlier—giving examples of each (in **Cases 1 and 2**). It is only important to distinguish that goal statements are more general than objectives. Objectives, on the other hand, are specific enough to provide standards or indicators of the eventual success of R&D.

What are the major differences between goals and objectives?

4.223 **Activities or tasks** refers to the relatively discrete R&D steps which must be taken to achieve the overall objectives. They actually become the units of work around which resources for the project (or the RDI) are planned and managed.

Why do we select tasks as units for planning R&D projects?

Frequently they are presented in sequence—one task leading to another, etc.

4.224 **Methods** is usually a more discursive section of a plan, in which particularly resource-intensive techniques for carrying out the activities or tasks, are explained.

4.225 **Schedules** refers to one of the most important elements of any plan. Schedules are needed to not only inform people when something may be accomplished, but also to help cost a project. For example, Project A requiring a researcher for one week would have less labour cost than would Project B requiring the same researcher for two weeks.

4.226(a) Finally we come to **resources**. Without them, the project does not get done (or the RDI does not exist). They are the principal reason we are planning: (1) to decide how much of what kind of resources we will need; (2) to justify our request for resources for the sake of those who control them; and (3) to provide a basis for controlling the expenditure of resources once they are granted to us.

4.226(b) **Resources** are all the people (usually discussed in terms of person-hours), equipment, facilities, raw materials, and money needed to conduct the effort. Later we will spend a lot of time on budgeting, which of course relates to the financial resource. But it is vital to acknowledge, now, that all the other resources must be bought, built, maintained, operated and replaced. All of these operations require money also. So when we talk about budgeting, or resources, we are talking about the fullest array of needs for effective R&D.

4.227 **Management Techniques** is a section which describes any important management considerations which may influence either the conduct of the project, or the resource requirements. An example would be the particular staff configuration required for the most efficient conduct of the R&D. Another would be the particular project plans for evaluation of project outcomes.

List typical R&D project resources that are used in your RDI:

Are you sure those are the only resources used in your RDI?

4.231 Steps in Planning: We are going to start our discussion of planning techniques with project planning. This is because the whole RDI, its resources, successes and failures depends on the conduct and results of R&D projects. But we have to stress again, that the same steps apply in planning at any other level. There are five, relatively simple steps to the project planning process:

- Identification of the problem
- Formulation of objectives
- Analysis of tasks
- Estimates of time and costs
- Synthesis of the plan

What does "synthesis" mean?

4.232(a) Identifying the Problem: The first step in planning an R&D programme or project is careful analysis of the problems which are to be solved by R&D. This includes specifying the intended beneficiaries of the R&D; their technology needs; the constraints and opportunities for application of new technologies; and the beneficiaries' role in the R&D process, itself.

4.232(b) It is important to recognize that, at this point, the kind of knowledge required for R&D planning relates to the beneficiaries of R&D, and their needs. In many ways this is a more important kind of knowledge than is knowledge of the technologies or R&D methods. In order to complete this first step in R&D planning, it may be necessary to travel to the "field" and make direct observations of the R&D end-users; their problems which necessitate the R&D; and their relative abilities to integrate new technologies into their work and living habits.

What is the role of R&D end-users in the first step of the planning process: identifying the problem?

4.232(c) Still another approach to this first step is to bring particularly articulate representatives of the proposed R&D beneficiaries into the laboratory to help develop the plan's statement of the R&D problem. In fact, even if a fieldwork approach is taken to this first planning step, it helps to pass the statement of the problem through a knowledgeable representative of the end-users—in order to double-check its validity and applicability.

Why do we stress a role for end-users in planning R&D?

4.232(d) A third approach to this step is the use of “extension workers” in interpreting the problem and need for R&D. These people usually live and work proximal to the intended beneficiaries of R&D. They usually have an intimate knowledge with the problems of development. They are, therefore, invaluable resources when it comes to characterizing development needs and the purposes of R&D.

4.232(e) **Project Objectives:** Project objectives translate statements of development problems and needs for R&D into specification of the technical targets for R&D activity. They form the transition between the needs and observations of non-technical beneficiaries of R&D; and the technical products and processes of researchers. They provide a focal point for R&D—the intended results of R&D, stated in technical terms.

What is the relationship between the nature of the development problem, and the statement of R&D objectives?

4.232(f) For these reasons, objectives are very important for ensuring the success of any R&D project. For example, it is possible for a project management team to examine the statement of the development problems and evaluate the adequacy of R&D objectives. In this case they would be asking, “Will achievement of these technical objectives fulfill the development needs of the intended beneficiaries of R&D?” If the answer to this question is negative, then the technical objectives should be changed until the answer is “yes.”

4.232(g) **Analysing Project Tasks:** The next step in planning is a study of the project to determine the technical approach and break it down into its component parts. Quite obviously, the success of this first step requires the expertise of technical specialists. Therefore it is vital to have project researchers involved in planning at this stage.

4.232(h) In planning, the project is broken down into its smallest discrete components for two reasons:

1. The time and cost for the project is easier to estimate, with greater accuracy, if it is done on the basis of smaller units of technical activity.

What does discrete mean?

Why is it important in isolating project tasks?

2. It is easier to monitor and control the progress of the whole project (a management activity which follows planning) on the basis of small units of technical activity.

4.232(i) Components of the project are defined not only in terms of technical criteria, but also in terms of management ones. For example, elements of activity which are conducted by supporting services in the RDI (like technical drawings which are done by the drafting department, or the acquisition of goods by the purchasing department) should be broken out into discrete components of the project.

4.232(j) There are four criteria for analysing any project into its component parts:

1. It is technically discrete.

2. It is temporally discrete.

3. It is financially discrete.

4. It yields discrete results.

TECHNOLOGY

TIME

FINANCES

RESULTS

}

What is their relationship?

4.232(k) By **technically discrete**, we mean that this component of the project involves a distinct and separate methodology, which can easily be distinguished from the technical work on other components. An example would be the fabrication component of a project to test the characteristics of a new agricultural implement. Fabrication requires mechanical engineering and assembly skills. Not design, agronomy, statistics, measurement, or any of the other technologies needed by this project. Fabrication of the prototype is a technically discrete component of this project.

METHODS

+

TIME

+

MONEY

=

RESULTS

4.232(l) By **temporally discrete** we mean that the component is easy to isolate in time. It may be that the component represents a unique phase in the sequence of the project. Or that it requires a relatively stable and easily estimated time for completion. An example would be the spawning season for a particular breed of fish. This period is regular and highly predictable—making it possible for fisheries researchers to plan their activities around it.

The basis for planning and the formula for success

4.232(m) By **financially discrete** we mean that the component has a relatively stable, and easily calculated cost. It is easy to predict the component's cost with a high degree of accuracy. An example would be the cost of subcontracted laboratory testing on a new alloy. The costs of this work are predictable and stable over time because we would base them on the proposed costs quoted by the contractor. Further, we would lock-in those costs via a commitment agreement with the contractor.

4.232(n) By **discrete results** we mean that the project component is completed when predicted results are achieved. That is, the component itself yields a well-defined and easily observed result. These results are frequently called "deliverables" in planning language. Such a deliverable could be something as sophisticated as the hybrid seed for a disease resistant plant, or simply a written report. In either case, the component is identified by completion of an easily observed deliverable.

4.232(o) **Estimating Time and Costs:** The second task in project planning involves estimating the time and cost requirements for each component of the project. Notice that the components (called "tasks") identified in the first planning step, serve here as the objects of time and cost estimates.

4.232(p) Time is estimated first, in terms of real dates. Sometimes these dates are prerequisites; that is, some agency or person with sufficient authority requires that certain R&D tasks be completed by particular dates. Other times, the date for starting a task can be estimated on the basis of expected completion dates for prior tasks; the availability of apparatus and material; the amount of time available; or past experience with a similar task. In all cases, note that good estimates require the knowledge and experience of project researchers.

4.232(q) History with similar tasks also helps estimate the duration of a research task. Here too, the availability of materials to work with is critical. Acquisition of them can use up a lot of time. The estimated date of completion, like the estimate of

Estimating costs is the subject of the next chapter on budgeting.

There is no doubt that accurate estimates require skill and experience.

But the greatest assistance comes from history?

Why? How can an R&D project director draw on history to help in estimating the costs of R&D?

start up date, has to be based on a number of factors which are usually well known by the research staff.

How can RDI accountants help make this job easier?

4.232(r) One of the keys for estimating real elapsed time for a task (hence start up and completion dates) also turns out to be critical for estimating the cost of the task. It is the estimate of person-hours, or person-days, required to complete the task. Obviously two people working for one day can do more work than one working for one day. In this case, two person-days were expended, while only one real-time day was used. Other tools for estimating costs will be detailed later.

4.232(s) **Synthesizing the Plan:** This is simply a matter of using particularly graphic symbols to depict the sequence of all project tasks; with their respective schedules and resource requirements. It is the heart of the project plan. With it a research manager can anticipate when a particular task will be done and how much it will cost.

4.232(t) But, the manager can also monitor on-going projects to be alert for cost over-runs, or delays in the scheduling. The plan gives the manager the ability to control the technical, time and cost performance of the project. Synthesis means pulling diverse parts together and creating a representation of the whole. In the case of project planning, this phase recreates the project, highlighting all its technical phases, deliverables, timing and resource requirements. There are a lot of graphic tools available for this purpose. Most of them are in use in RDIs around the world. Probably many of them are familiar to you.

Why would we be interested in graphical tools for synthesizing a project plan? Why aren't words sufficient?

4.232(u) Nonetheless, we will explain six techniques here, along with their merits and demerits as tools for planning, monitoring and control of R&D. These tools could be applied to projects, as we will do here. Or they could be applied to a collection of projects which comprise an R&D programme. Finally, they could even be applied to an RDI (many R&D programmes) in strategic planning. They are:

- Task Lists
- Bar Chart
- Deliverables Chart
- Critical Path Method (CPM)
- Programme Evaluation and Review Technique (PERT)
- Analysis Bar Charting (ABC)

4.241(a) Task Lists: This is the most common approach for displaying a R&D project plan. It consists of a listing of the tasks comprising a project, in a column down the left side of a page. It is possible to array most scheduling and cost data in the remaining parallel columns. For example, the next column could present start-up dates for the tasks; the next one, anticipated completion dates; the next, elapsed time; the next, person-days; next, total cost for labour; etc.

Does your RDI use task lists for any purpose now? Give an example.

4.241(b) The merits of this approach are that it is easy to compose and to read without special training in the interpretation of symbols. However, its greatest drawback is that it does not show the relationships among tasks. For example, some of them may be able to function simultaneously; whereas, some may not be able to start, before the completion of others. This is hard to show in a simple listing. The information is present to deduce those kinds of relationships; but they are not obvious.

What do we mean by relationships among tasks of an R&D project?

Figure 3. Task List Approach to Synthesizing a Project Plan

<i>Project Title: Development of a Production Model, and Specifications for a Marine Fisheries Ultra High Frequency (UHF) Radio Receiver</i>				
Project Task	Start	End	Months	
1. Literature Search and Study	May 1	Aug 30	4.0	
2. Develop Performance Specs	June 1	Sept 30	4.0	
3. Design Electronics	June 1	Nov 15	5.5	
4. Make Circuit Boards and Test	Aug 15	Nov 15	3.0	
5. Design Mechanics	June 1	Dec 15	6.5	
6. Develop Parts Lists	Aug 15	Sept 30	1.5	
7. Make Engineering Model	Sept 1	Nov 15	2.5	
8. Test Engineering Model	Oct 15	Dec 30	2.5	
9. Design Necessary Changes	Oct 15	Jan 15	3.0	
10. Draw Schematics	July 15	Jan 30	6.5	
11. Write Monthly Progress Rpts	May 15	Feb 30	9.5	

Exercise 3: Analysing a Task List

Examine this Task List with the trainer and colleagues. What are its merits and demerits as a tool for planning R&D? Answer these questions:

1. Does this plan format adequately identify project tasks?
2. Are expected start-up and completion dates clear?
3. Which task will require the most time to complete? (Be careful!)
4. Which task will be completed last?
5. Does the format tell planners which tasks require most staff time? (Watch out!)
6. Which tasks will be most expensive? Look at the time for each (the last column of the table)?
7. Which tasks are critical to the success of other tasks?
8. During this project, where will we encounter slack time; when the greatest number of project staff are not working? (Really?)
9. Where are probable activity bottlenecks—when we will have the most staff working at the same time? (How do you know?)

DO NOT TURN THE PAGE until you want our answers.

(Exercise 3: Continued)

OUR ANSWERS to the nine questions above:

1. Yes; and more detail can be added if it is desired.
2. Yes; assuming it is known what years are involved.
3. What is "time?" Task #11 is done throughout the project period (9.5 months). But it obviously requires far less staff time than do the technical tasks. This Task List does not help us answer this question.
4. Monthly report for February 30.
5. No.
6. No; because they may require different numbers of staff.
7. This Task List does not tell us this.
8. We cannot tell from this Task List.
9. We cannot tell because time is not calculated in person-days.

In sum, what does the Task List tell you about the project?

1. _____
2. _____
3. _____
4. _____
5. _____

And, what does it NOT tell you about the project?

1. _____
2. _____
3. _____
4. _____
5. _____

DO NOT TURN THE PAGE until you want our answers.

(Exercise 3: Continued)

OUR ANSWERS to the ten questions, above:

What the Task List does tell us.

1. Specific tasks comprising the project.
2. Planned start-up dates for each task.
3. Planned completion dates for each task.
4. Planned elapsed calendar time per task.
5. Which tasks will be implemented at the same time.

What the Task List does NOT tell us.

1. Critical relationships between tasks; for example, which have to be done before others can start. And, which can operate concurrently without interfering with each other?
 2. Level-of-effort to complete tasks; e.g., person-days per task.
 3. Slack (or "float") time.
 4. Activity bottlenecks.
 5. Schedule of deliverables.
-

4.242 Task List Weaknesses: The weaknesses in the Task List make it difficult for us to anticipate problems we may have in completing this project on time (and therefore, within budget). If everything goes as planned (and when does that ever happen?!), then the Task List serves as a good planning tool. But, if any task deviates from the planned dates, others will probably shift also. Yet the Task List does not give us a clue about which tasks are so related. Nor does it allow us to anticipate when and where those shifts might take place.

With a Task List, how can you tell when one task requires the completion of another, before it can start?

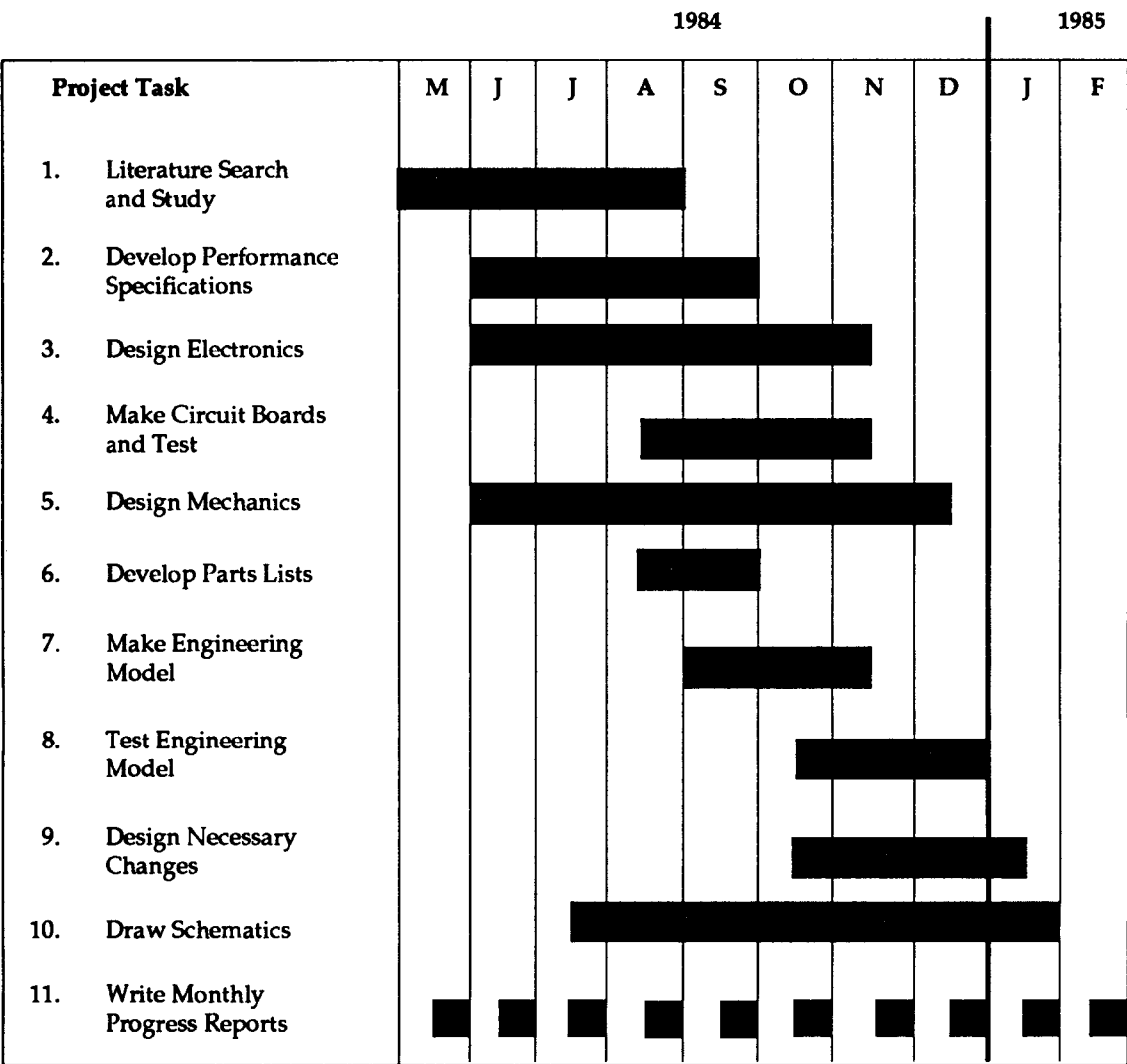
4.251 Bar Charts: A lot of RDIs use bar charts. Basically, they are two-dimensional charts with the tasks listed vertically on the left margin, and a

time line “arrayed horizontally at the top”. Then lines (or “bars”) are used to indicate the start-up, duration, and completion times for each task. They are an improvement over the Task List because they are more graphic; they show the relationship of tasks, to each other, over time; and they accommodate a variety of information. Figure 4 shows a typical Bar Chart.

Does a Bar Chart help you do it better? Explain!

Figure 4. Bar Chart Approach to Synthesizing a Project Plan

Project Title: Development of a Production Model, and Specifications for a Marine Fisheries Ultra High Frequency (UHF) Radio Receiver



Exercise 4: Analysing a Bar Chart

Go back to the nine questions in **Exercise 3** and answer them from an examination of this Bar Chart. Try to determine how much more, or less, planning information is provided by a Bar Chart, than by a Task List. Which format do you prefer? Why? Write your answers to the nine questions here:

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____

DO NOT TURN THE PAGE until you want our answers.

(Exercise 4: Continued)

OUR ANSWERS to the nine questions in **Exercise 3:**

1. Yes
2. Yes
3. It is still hard to be certain especially if "time" refers to worktime (person-days for example). But if it means calendar time, it looks like Tasks #5 and #10 probably require the most time for completion. But that does not mean they require the most manpower, equipment, facilities, money or any other resource. They may not be the most expensive.
4. The last technical task will be Task #10 on January 30. Otherwise, the Monthly Report for February is the last task.
5. No.
6. No.
7. We still do not know the answer to this one.
8. It looks like May of the first year, and January of the second.
9. We cannot tell for sure because time is not calculated in terms of person-days. But, it would be a good guess that bottlenecks could occur during the months of August, September and October. You can guess by looking for the greatest overlap of bars in any single month.

In sum, what more can you learn from a Bar Chart, that you cannot learn from a Task List?

1. _____
2. _____
3. _____
4. _____

DO NOT TURN THE PAGE until you want our answers.

(Exercise 4: Continued)

OUR ANSWERS to the questions asked at the bottom of the last page:

1. The Bar Chart provides a better depiction of task duration. It is therefore, easier to comprehend the planned schedule of these events.
 2. The Bar Chart shows the periods of time during which the fewest number of tasks are being implemented; it therefore, provides a better guess of probable slack periods.
 3. The Bar Chart shows the periods of time during which the greatest number of tasks are being implemented; it therefore, provides a better guess of probable bottle-necks.
 4. The Bar Chart does a better job of emphasizing those tasks which require the greatest, and least, duration—a useful observation even though it does not necessarily imply anything about level-of-effort or costs.
-

4.252(a) **Bar Chart Weaknesses:** The Bar Chart is little better than the Task List, in terms of the amount and type of information it provides the planner. However, it is a more communicative device, than is the Task List. The bars, being pictures, are easier to understand than are a table of words or numbers.

What is the difference between a Task List and a Bar Chart?

4.252(b) That notwithstanding, the Bar Chart still does not show us the required sequence of tasks, or the functional relationships among them. It does not highlight particularly critical tasks. It does not give us a precise fix on slack time or bottlenecks. And, it makes it very difficult to predict the need for timely decisions.

What does the Bar Chart show about project tasks—that the Task List does not show?

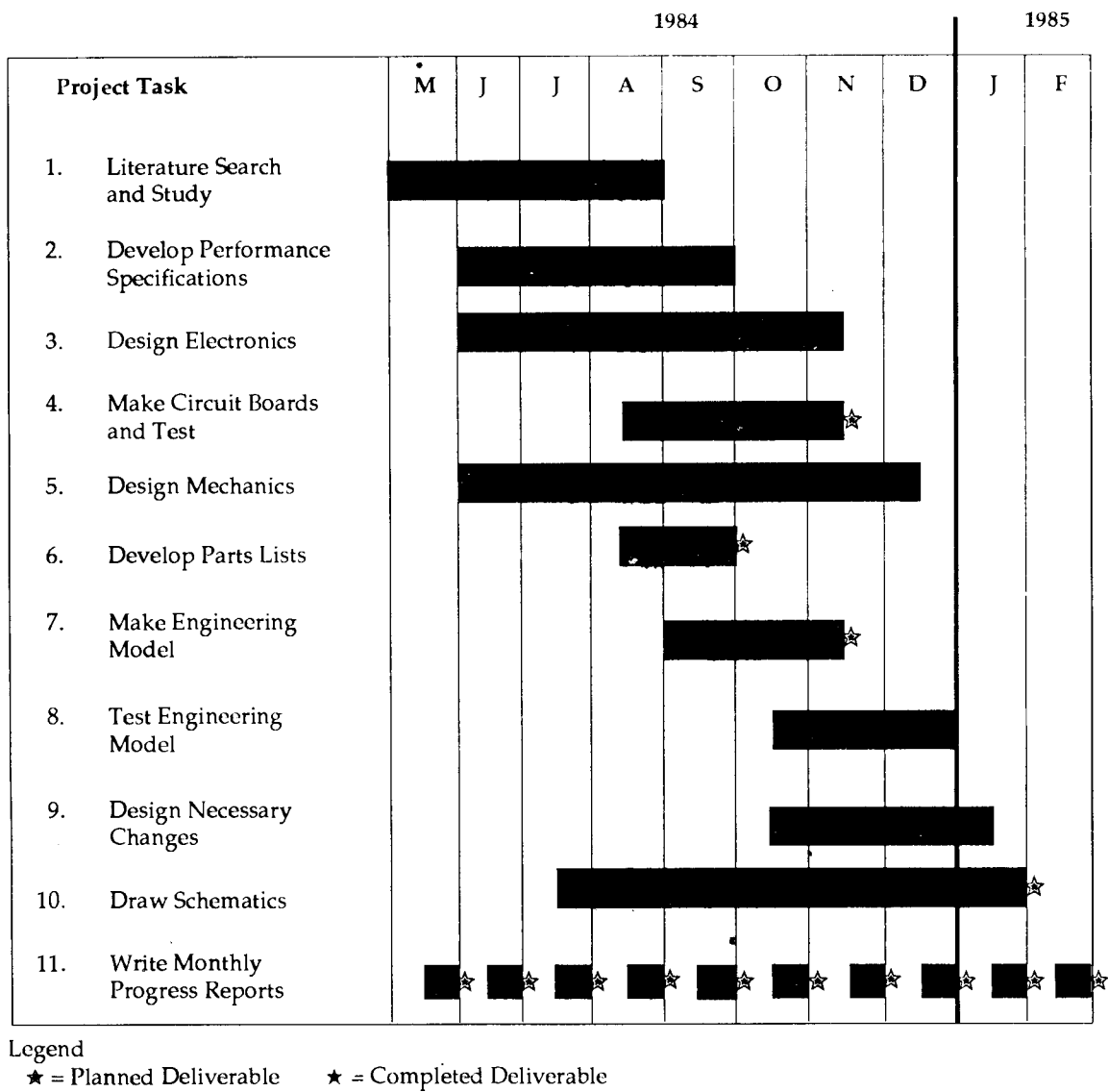
4.252(c) The standard Bar Chart, like that in Figure 4, can be improved by the addition of symbols for more information. In fact, the Deliverables Chart is an adaptation of a Bar Chart.

4.261 **Deliverables Chart:** In the Deliverables Chart we try to add some of the information which is missing from either the Task List, or the Bar Chart. In particular, we try to **identify which tasks yield particularly noteworthy deliverables, and when.** This information helps project people, senior RDI managers and other constituents of the R&D project anticipate and respond to particularly significant developments in the project. See Figure 5.

What is a deliverable?

Figure 5. Deliverables Chart Approach to Synthesizing a Project Plan

Project Title: Development of a Production Model, and Specifications for a Marine Fisheries Ultra High Frequency (UHF) Radio Receiver



Exercise 5: Analysing a Deliverables Chart

Compare the Deliverables Chart (**Figure 5**) to the Bar Chart (**Figure 4**). Discuss with your instructor(s) and fellow participants, their similarities and differences. Answer these questions:

1. What do the open stars in the Deliverables Chart signify?
2. What new planning information is provided in the Deliverables Chart?
3. Who is interested in this new information; why are they interested?
4. Why is the closed star included in the legend for this Chart?

DO NOT LOOK BELOW until you want our answers.

OUR ANSWERS to the four questions above

1. The open stars in the Deliverables Chart indicate both the tasks, and dates, when project constituents may expect the research work to yield significant deliverables—that is, results which indicate significant progress toward fulfillment of the project objectives.
 2. The deliverable symbols help us note particularly significant tasks. The tasks which generate these deliverables are the ones which managers will want to monitor particularly closely. They will want to be on the search for ways to ensure that these particular tasks are conducted effectively, efficiently and within resource constraints.
 3. Of course project managers are interested in this information because the success of their project depends, in large part, on the outcomes of these particular tasks. But, other constituents of the project are also interested. These deliverables frequently have a way of becoming known outside the realm of the project team itself. RDI senior management frequently monitors R&D progress through particularly significant deliverables like these. But, constituents outside the RDI do also. Clients in the private sector (farmers, industrialists, professionals, and even the public) monitor an RDI through its deliverables. Government officials (particularly those responsible for the RDI) may also be interested in these deliverables.
 4. The closed star is in the legend for this Chart because it will be used by project planners when, and only when, a deliverable is actually completed. After all, the open stars only tell us when we can expect to complete the deliverables—if all goes as planned. But when did things ever go as planned? The closed star is added to the Deliverables Chart, as the project unfolds; and differences in the location of the open and closed stars (for the same task) will help planners monitor schedule performance on this project.
-

4.262(a) Deliverables Chart Weaknesses: Well we have made a significant improvement in our format for synthesizing a project plan, with the addition of a deliverables symbol to the Bar Chart. The Deliverables Chart helps us discern which tasks are particularly important for ultimate completion of the project.

What is slack time?

4.262(b) But we still need to know more: where is the slack time, or the bottlenecks; what is the most efficient way to complete this project; how should we distribute resources to ensure that we complete the project on schedule? Even the Deliverables Chart cannot tell us.

What are bottlenecks?

4.271(a) Networking: One of the greatest shortcomings of the three project planning formats already presented is their simplicity. They are not particularly useful for complex projects. In truth, many typical R&D projects encounter the need to complete tasks which could not be anticipated. Where do they fit in a Task List or a Bar Chart? How can these earlier formats handle unanticipated deviations from the plan?

4.271(b) The answer is, they can't! But networking can. Networking is a lot like drawing an organization chart. A network is a logical sequence of project tasks and deliverables. It is sort of like drawing a roadmap, in which the cities are the deliverables (the destination for research work), and the roads connecting them are the research tasks. In networking, we are simply drawing a map of the research project.

What is networking?

What can it do for R&D planning that cannot be done by either Task Lists, Bar Charts, or Deliverables Charts?

4.272(a) Work Breakdown Schedule: Just like making plans to travel, we first have to know three things about the trip:

- What are stops along the way
- What is the distance to them
- How do they relate to each other

What is a Work Breakdown Schedule?

4.272(b) Breaking a long trip down into these three elements helps plan the safest and most comfortable route.

4.272(c) Having similar pieces of information about a R&D project will permit us to plan its

What kind of information does it provide about an R&D project?

efficient execution also. We have to know:

- The intermittent tasks (stops along the way)
- The duration, or amount of time, to achieve each one (distance to them)
- Which ones have to be done first (how they relate to each other)

4.272(d) Now those three pieces of information are very much like what we arrayed in the Deliverables Chart (see Figure 5). We know the tasks which comprise the project. We know the elapsed time to completion of each task (it can be read from the Bar Chart, or the Deliverables Chart). And, the open stars in the Deliverables Chart give us some idea of the relationship among tasks.

4.272(e) A better idea of the relationship among tasks can be had by simply examining the tasks themselves—and relying on the good judgment of subject area specialists. What we want to know about them is which are necessary precursors of others. In other words, which ones have to be commenced, if not completed, before others can begin. Our UHF Radio Receiver project can be arrayed in a Work Breakdown Schedule, as in Figure 6.

What do we mean when we say that one R&D task is the precursor of another task?

Figure 6. Work Breakdown Schedule for the UHF Radio Receiver

Project Tasks		Duration (Days)	Preceding Tasks
1.	Literature Search and Study	80	–
2.	Develop Performance Specifications	80	1
3.	Design Electronics	110	2
4.	Make Circuit Boards and Test	60	3
5.	Design Mechanics	130	2
6.	Develop Parts List	30	4, 5
7.	Make Engineering Model	50	2
8.	Test Engineering Model	50	7
9.	Design Necessary Changes	60	4, 8
10.	Draw Schematics	70	9
11.	Write Monthly Progress Reports	100	Concurrent

4.272(f) The third column in **Figure 6** shows the numbers of tasks which must show some results before we can start the corresponding task in the first column. For example, look at the entry for project task number 2: Develop Performance Specifications. The third column says that the Literature Search and Study (task number 1) must show some significant results before we can commence task number 2. That makes sense. As with a project in any sector, technical performance specifications can, hopefully, be derived from a careful examination of what is already known and published in relevant literature.

4.272(g) Or, look at the entry for project task number 6: Develop Parts List. This is the list which will tell manufacturers and users of the radio receiver what inventory is needed to build and maintain the radios. But we cannot develop this parts list until we have a pretty good idea of the parts that are needed for the electrical and mechanical functions of the radio. Therefore, as the third column in **Figure 6** shows, task numbers 4 and 5 must begin to show significant results before number 6 can commence.

4.272(h) Finally, what do we do with the 11th project task: Write Monthly Progress Reports? In truth, it is something that has to be done every month regardless of the project progress, or lack of progress. In fact, this activity, while an important part of project management, is relatively independent of progress on the project. It is not even an R&D task. It is an administrative task. So let us decide, right here and now, to eliminate it from our network. The principal criterion for eliminating a task from the network is the answer to the question:

- Does progress on the project depend on the execution of this task?

4.272(i) In this case, the monthly report activity is relatively independent of project progress. In other words the project progress does not depend on the quality or frequency of monthly activities reports. So we will not include it in the network.

4.272(j) That is the Work Breakdown Schedule. It is like a preliminary step in planning a long trip by automobile. It lists the major cities along the way (project tasks); the distances between them (duration per task); and the principal routes from one to the other (preceding tasks). It only remains to draw the map to our final destination.

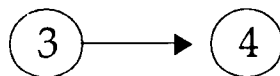
4.273(a) **Drawing a Network:** Drawing the network is relatively straight forward. First we must pick a symbol to depict our intermittent destinations (the project tasks). How about a circle with the task number inside it. Here, for example, would be task number 1: Literature Search and Study:



What does the number mean?

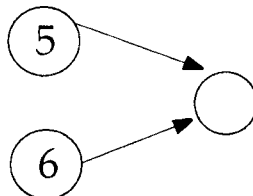
4.273(b) Using the task number instead of the name eliminates the need to make a roadmap big enough to accommodate all those words.

4.273(c) After we get two or more tasks on paper, we connect them with arrows which signify our route from one to the other. If the two tasks are side-by-side, then progress on the project is indicated by an arrow between them which runs from left to right; like this:



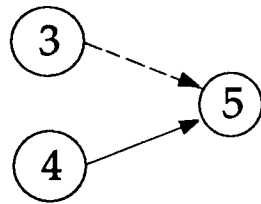
What does the arrow mean?

4.273(d) But if the two tasks can be done simultaneously, then they will appear one over the other; like this:



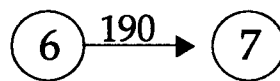
Why are these two tasks stacked on top of each other?

4.273(e) If there is no very significant functional relationship between tasks, then no arrow connects them. If information from one task is important for the progress of another task, but neither task ultimately depends on the completion of the other, then we connect them with a broken (or dotted) arrow; like this:



What does the dotted arrow mean?

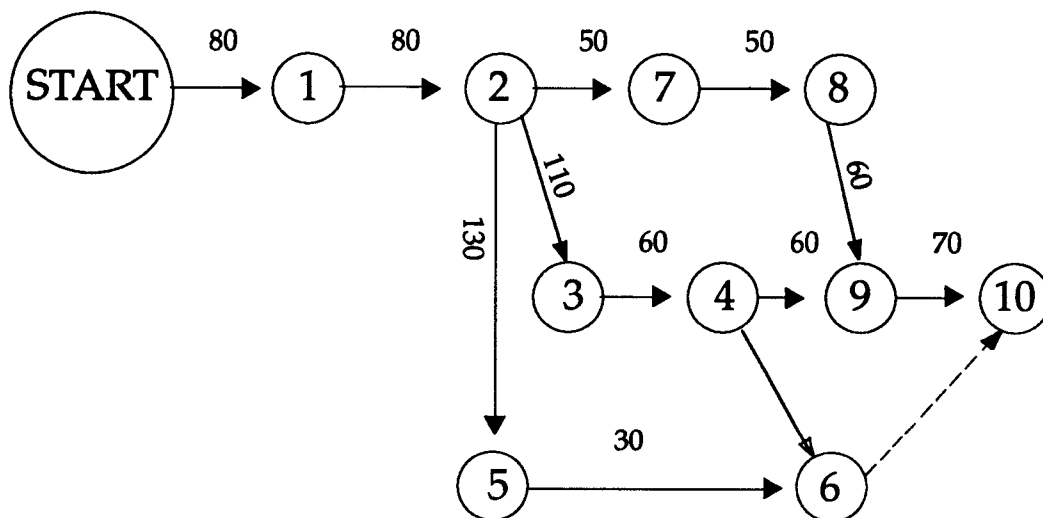
4.273(f) Only one instruction remains. Let us put the distance between cities (duration to complete a task) on the map also. That way we will be able to figure out how much time is going to be needed to complete the whole trip. We simply insert the figure over the arrow connecting tasks; like this:



*What does the number "190" mean?
Why is it on the line?*

4.273(g) Now we are ready to draw the network for our UHF Radio Receiver project. Figure 7 shows the results.

Figure 7. Network Drawing for the UHF Radio Receiver Project



4.273(h) Notice something about this network. The circles represent arrival at our intermittent destination; or completion of the intermittent research task. That is why the network does not start with the first task; it has to be executed before we come to the circle with a 1 in it. Therefore, the network begins with a circle labelled "Start".

Exercise 5: Drawing Planning Networks

Take ten minutes to complete network drawings for two hypothetical projects. Their Work Breakdown Schedules appear below (without duration estimates, for the time being). Study each schedule and practice drawing the network on note paper until you feel confident you have the best solution. Then draw the final network here—to the right of the Work Breakdown Schedule. We started each network by drawing the Start circle for you. The rest should be easy; right?!

Project Task	Preceding Tasks
A	—
B	—
C	A, B
D	C
E	C
F	D, E

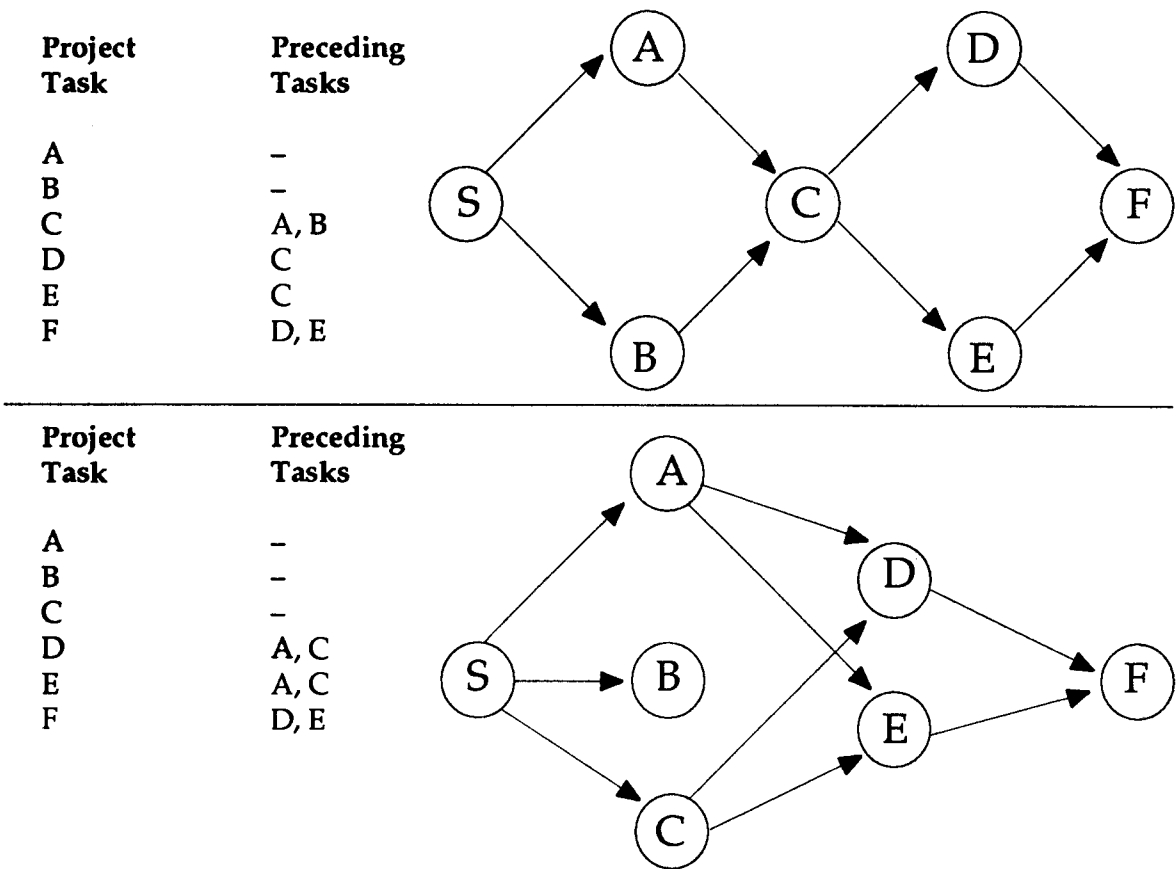
Project Task	Preceding Tasks
A	—
B	—
C	—
D	A, C
E	A, C
F	D, E

(Puzzle: What happens to B in a network like this?)

DO NOT TURN THE PAGE until you want to see our drawings of these networks.

(Exercise 5: Continued)

Here is our version of these two exercise networks:



Your drawing may not look exactly like ours. But does it achieve exactly the same ends? Here is another one for you. For this one, team with two other people and work on it together.

[Instructor(s) circulate among the teams and oversee their progress. Look for standard problems and creative solutions which you can bring to the attention of the whole group.]

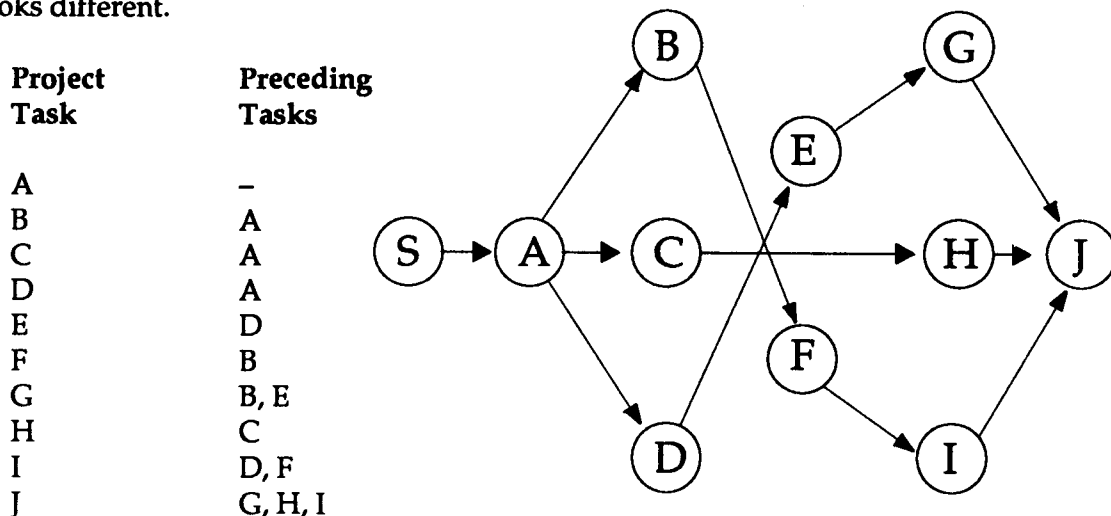
Project Task	Preceding Tasks
A	-
B	A
C	A
D	A
E	D
F	B
G	B, E
H	C
I	D, F
J	G, H, I



DO NOT TURN THE PAGE until you want to see our drawing.

(Exercise 5: Continued)

Here is our version of this last exercise network. Does yours resemble it in terms of the relationships among all the tasks for the project? It should, even if the drawing itself looks different.



The only rule about the way you layout your network drawings (beyond getting the relationships among all tasks exactly right) is to make the drawing as neat, and simple as possible. The research and development process is tough enough without presenting researchers with unnecessarily complex network plans.

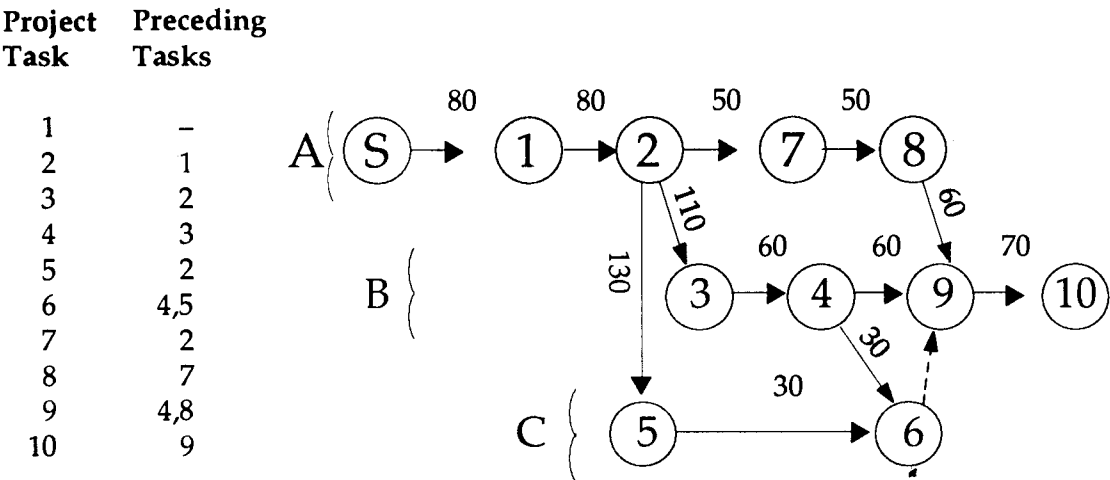
4.274 Review: Let us review; what are we trying to do?

1. Through the use of tables, graphs and charts called "networks", we are trying to develop ways to anticipate and control the technical, time, and cost performance of R&D projects.
2. These, and other, tools comprise project planning; an activity which serves as the foundation for any institute-wide planning.
3. Through it all, we must remember that the ultimate criterion for the success of any RDI, is the success of its individual R&D projects. Therefore, we are starting the planning process at the project level.
4. R&D project staff have a critical role in developing these project plans. It is not a job for administrators and managers, only.

4.281(a) **Quantitative Planning:** Now it is time to get something more out of these networks. What can they tell us, besides the chain of R&D tasks?

4.281(b) This is where networking proves to be a more powerful planning tool than either Task Lists, Bar Charts or Deliverables Charts. Networking can help us isolate that route to project completion, which has the least amount of slack time in it. In other words, any delay along this particular route holds up the whole project (and of course, ends up costing more).

4.281(c) Take another look at the UHF Radio Receiver network which we have redrawn below:



4.281(d) How can we anticipate the minimum amount of time this R&D project will require for completion? How do we know what route to take to ensure that we cover the distance? What route is critical to our planning? In other words, if we encounter any resource shortages or other causes of delay along this route, then the whole project is in jeopardy of delays and cost overruns. How do we determine this vital route, or "critical path," as planners call it?

It might be possible to draw this network with the arrows scaled in proportion to real time. It depends on the complexity of the project, the scale and the size of the drawing.

4.281(e) Looking at the network again, we can see that the road splits at task number 2. We can proceed straight east to task number 7; we can go southeast to task number 3; or we can go south-southeast to task number 5. In truth, this project will only be complete when we have covered all three routes. But which one of them is going to

require the closest monitoring and control of resources in order to ensure that we complete the project on time?

4.281(f) We have labelled these three paths A, B, and C in the drawing. Now it is time to find out how much time is required to complete each one. This is simply done by adding the durations noted on the arrows. Like this:

Path A	Path B	Path C
80	80	80
80	80	80
50	110	130
50	60	30
70	60	–
60	70	–
<hr/> 390	<hr/> 460	<hr/> 320

4.281(g) Now we have a good idea about how much time is required to complete each path. The critical path is which one? A? B? C?

Why is the critical path called "critical"?

4.282(a) The **critical path** is that path which takes the greatest amount of time to accomplish. It is critical because if any delays occur in it, then they delay the whole project. Paths which require less time for completion, can be delayed for a time equal to the difference between the duration of the critical path, and that of the other path.

Is "slack time" the same as "wasted time"? Explain!

4.282(b) Did you decide that path B in our UHF Radio Receiver network was the critical path. We agree. It requires 460 days to completion. All the other paths can be accomplished sooner. In fact there is $460 - 390 = 70$ days of slack time in path A, isn't there? How much slack time is there in path C?

Do R&D managers plan for slack time in your RDI?

4.282(c) This information tells R&D project managers just exactly which project tasks are most important for the efficient and economical management of the project. It says watch out most closely for those six activities on path B; because any delays there will set the whole project back. Plan ahead particularly for these tasks. Get the supplies in before hand; have the appropriate specialists identified and ready to go to work;

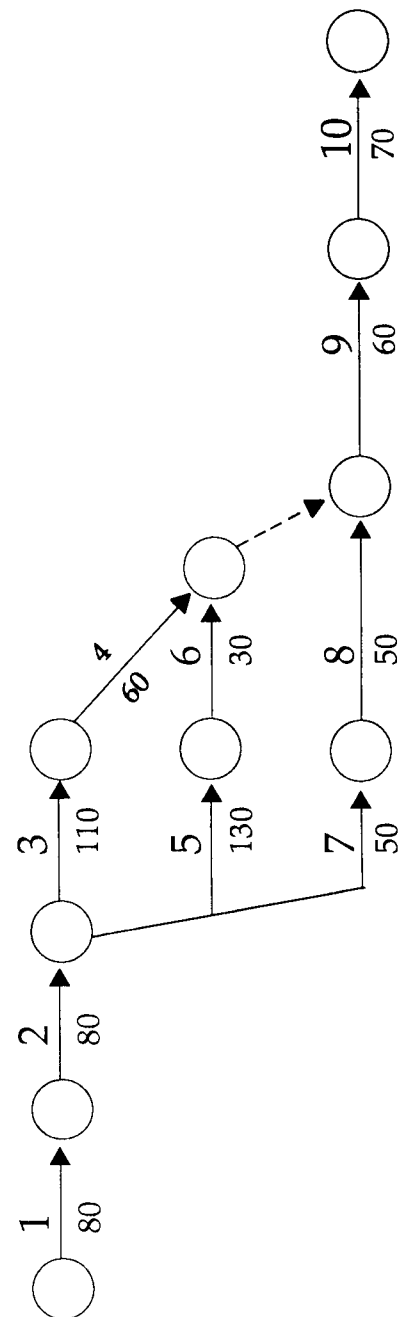
prepare the facilities; and do whatever else is necessary to bring these tasks to completion within planned expectations. If something slips along path A, that is not as critical. This critical path analysis truly serves as a tool for planning R&D priorities.

4.283 Three Kinds of Networks: There are quite a variety of networks available to R&D planners. In fact, most R&D planners find ways to invent some version of their own—one which best suits the uniqueness in their institution and their purposes. However, three versions are prominent in the literature, and experience. Since they are more likely to be frequently encountered, we mention them here.

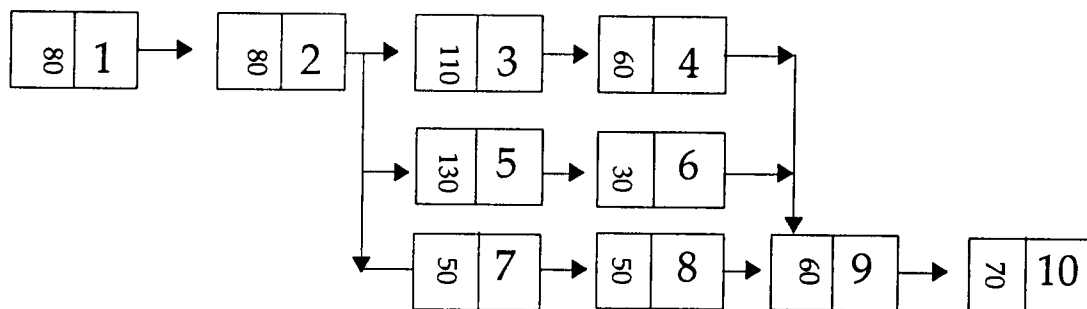
4.284 PERT: PERT, as it is often called, stands for Programme Evaluation and Review Technique. It was developed by a military consultant to help plan complex military projects. It is little more than what we have been doing with networking so far in this workshop. Each node (circle) in the network stands for an R&D task started or completed.

4.285 CPM: CPM, of course, stands for Critical Path Method. We have applied the quantitative techniques of CPM to our PERT charts already haven't we. There is one more possible adaptation of the network, however. True CPMers like to think of the R&D task on the arrow. That way the circles simply indicate junctions where the arrows meet, and depart. Here is another network for our UHF Radio Receiver project. It is drawn with the R&D tasks on the arrows, instead of in the nodes. Compare it to the PERT chart two pages back. There is not much difference in appearance, and none in the quantitative analysis of the critical path.

4.286(a) ABC: ABC is just another format for networking. It combines the techniques of the Bar Chart, and PERT. The initials stand for Analysis Bar Charting. Basically, it uses a rectangle (or "bar") in place of our circles in the PERT chart. But this is not the only difference. The rectangle shape of nodes gives us a lot of corners around which to place numbers which help us plan and control



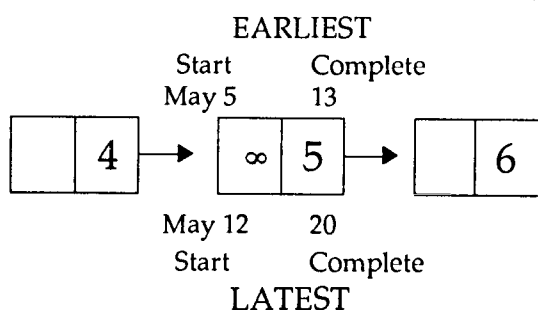
project scheduling. Here is a plan for our UHF Radio Receiver project, done with ABC (by the way, if you have forgotten what our project task numbers mean, you may refresh your memory by examining the Work Breakdown Schedule):



4.286(b) The ABC format does not look very different from the others, does it. The large numbers represent our project tasks. The small numbers represent the duration we expect each task to require. They form the basis of our scheduling. Now comes the interesting part. By placing real calendar dates at the corners of each rectangle, we can come pretty close to accurately predicting dates for completion of each task—hence the whole project. First let us look at a simplified example:

Don't forget: The basis for all networking is the Work Breakdown Schedule!

What is a Work Breakdown Schedule? What information does it provide about the R&D project, or programme?



4.286(c) Those numbers outside the four corners are actual days of the month. Usually the Start dates are based on factors external to the task—like completion of the previous task, or arrival of parts and materials, etc. However, the Completion dates derive from the addition of the duration (in the small rectangle) to the Start dates, i.e., $5+8 = 13$ and $12+8 = 20$.

Which number represents the difference between start and completion dates?

4.286(d) Consequently, planning actual dates is fairly simple with Analysis Bar Charting. The difficult judgment is the Start date; and if the task follows on the heels of a previous one, even that is easy. The balance of scheduling with ABC is simply a matter of mathematics. The difference between Earliest and Latest Start provides the planner opportunity to anticipate delays; and plan for them. It permits the RDI manager to think about how delays in this project may impact other projects and the RDI as a whole.

What accounts for differences between EARLIEST and LATEST start dates?

4.286(e) This same kind of quantitative planning is possible with either PERT or CPM. It is just easier to depict with ABC.

4.286(f) Another potentially useful quantitative technique for predicting task completion dates comes from the PERT process. Some planners recommend estimating three durations for each task:

- Optimistic estimate (O)
- Most likely estimate (M)
- Pessimistic estimate (P)

4.286(g) They then quantitatively develop an Expected estimate (E) with the formula:

$$\frac{O + 4(M) + P}{6} = E$$

Why is the most likely estimate multiplied by 4 in this formula?

4.286(h) Both of these quantitative planning techniques are only examples of the kinds of planning tools available with networking. Further, you can invent your own depending on your needs. Let us take a break and try a few exercises using both of these techniques.

Why is the sum of these estimates divided by 6?

Exercise 6: Quantitative Planning with Networks

Below is another drawing of our UHF Radio Receiver project. It is like the previous one except we dropped a zero (0) from the durations (same as dividing each duration by 10) in order to make it easier to work with the numbers. Your task is to answer these two questions:

1. What is the Earliest Completion date for this project?

Your answer: _____
 Month Day

2. What is the Latest Completion date for this project?

Your answer: _____
 Month Day

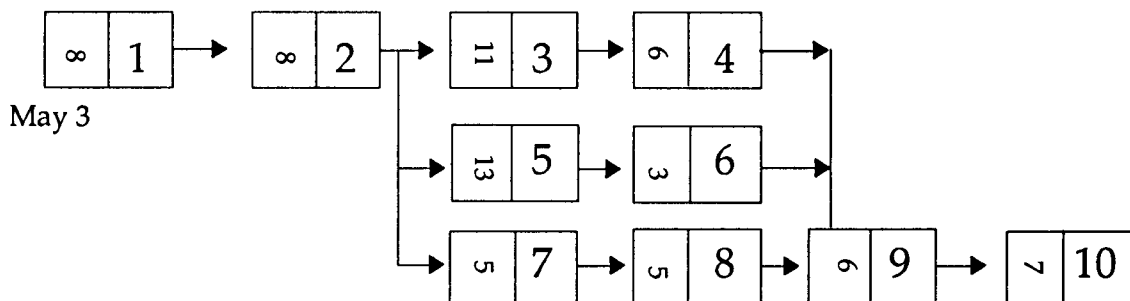
Here are some assumptions you should keep in mind as you do this exercise.

1. The Government has placed the highest priority on this UHF Radio Receiver. Therefore every day of the month is a workday.
2. Each task starts on the first day after the previous task is done.
3. The Latest Start day for each task is two (2) days later than the Latest Completion day of the previous task.

Hint: You may want to use your calendar.

We have placed two dates on the network for you. You must calculate the rest of them. Why don't you try it a few times on note paper, until you feel you have the right answer. Then, enter the correct dates on our drawing. Good Luck !

May 1



(Exercise 6: Continued)

Now only one task remains. Calculate the Expected (E) date of completion for this project using the formula on the last page. Here is the set of assumptions, based on the same ABC drawn above:

1. The Optimistic estimate (O) is the number which appears in the rectangles of the ABC drawing, above.
2. The Most likely estimate (M) may be calculated by adding one (1) day to O.
3. The Pessimistic estimate (P) may be calculated by adding two (2) days to M.
4. Round your calculation to the nearest whole day.

Hint: Watch out for tasks which can be completed simultaneously.

If we start the project on May 1, on what date will it be completed (use your calendar and the same assumptions used for the ABC exercise)?

The project will be completed on _____
Month Day

How does your answer using the formula compare to that based on the ABC method?
DO NOT LOOK BELOW until you are ready for our answers.

OUR ANSWERS to these two planning exercises.

ABC Exercise

1. What is the Earliest Completion date for this project?

Our answer: **June 22**

2. What is the Latest Completion date for this project?

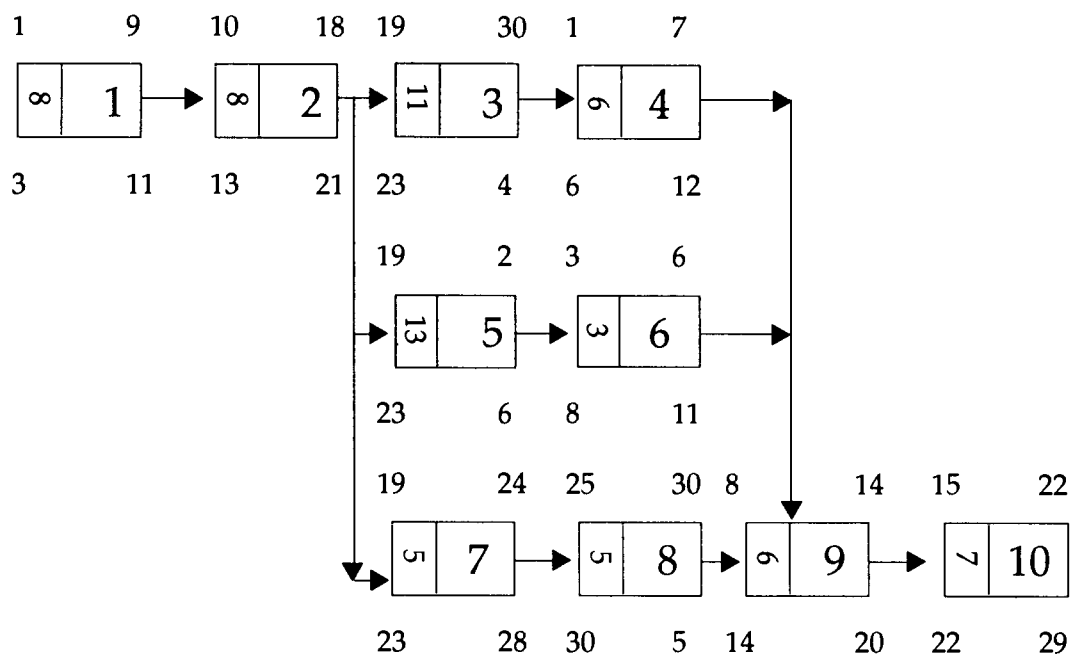
Our answer: **June 29**

Formula Exercise

1. The project will be completed on **June 22**.
2. The Earliest Completion date calculated by the ABC method, and the completion date calculated using the CPM/PERT formula are the same.

The ABC drawing with our dates affixed, appears on the next page.

(Exercise 6: Continued)



Here is the table of data we used to calculate the Expected date of completion (E) with the CPM/PERT formula:

Task	O ¹	M ²	P ³	E
1	8	9	11	9.16
2	8	9	11	9.16
3	11	12	14	12.16
4	6	7	9	7.16
9	6	7	9	7.16
10	7	8	10	8.16

¹Taken from ABC diagram.

²O+1 day.

³M+2 days.

Here is the logic of our analysis; does it match your own?

1. The sum of E for Tasks 1–4 plus 9–10 = 52.9 or 53 days.
2. May has 31 days (check your calendar).
3. The sum of E minus the days in May = 53–31 = 22 days.
4. Therefore the project will require all of May plus the first 22 days in June.

(Exercise 6: Continued)

Notice: In our calculations using both methods, we derived our final dates by calculating only along the Critical Path. This is because Tasks 5–8 could be done within the time constraints of Tasks 1–4. In the ABC exercise, this judgment was made when we were forced to calculate Earliest and Latest Task for Task 9.

[Instructor(s): You may wish to conduct these exercises with small teams of participants (2–3) working together. That may make it more interesting and more expeditious for all participants. Actually, you could assign the ABC exercise to half of the group, working in teams; and the CPM/PERT formula exercise to the other half, working in teams. That would provide some variety and interest for all—particularly if you then had select groups report their results to the participants in plenary. If you do use this latter approach, though, be sure to permit enough time for the participants to copy the results, including calculations, for the exercise conducted by the other half of the class. That notwithstanding, these are also good exercises for overnight work in teams, or individually. They could even be treated as hand-in assignments for you to read over and make individual comments. Adapt the format to your style of training, the participants’ styles of learning, and your schedule.]

4.291 Review: Let us take a moment to review the most important points about networks. A **network, is a graphical representation of the logical relationship among principal tasks comprising an R&D project.** Or, it could represent the logical relationships among R&D projects which comprise an R&D programme. We use a network to:

Do project or programme plans in your RDI accomplish each of these?

	NO	YES
1. Identify each critical R&D project task.	<input type="checkbox"/>	<input type="checkbox"/>
2. Reduce the possibility of overlooking important tasks in the execution of the project.	<input type="checkbox"/>	<input type="checkbox"/>
3. Show the relationships, logic and sequence among project tasks.	<input type="checkbox"/>	<input type="checkbox"/>
4. Determine when a task may be started or completed, and target dates for deliverables.	<input type="checkbox"/>	<input type="checkbox"/>
5. Anticipate likely bottlenecks and plan resource needs in advance.	<input type="checkbox"/>	<input type="checkbox"/>
6. Anticipate slack time so that valuable resources may be reallocated to other projects.	<input type="checkbox"/>	<input type="checkbox"/>

7.	Improve resource allocation decisions by providing more timely information.	NO <input type="checkbox"/>	YES <input type="checkbox"/>
8.	Reduce total project time by improving time control.	<input type="checkbox"/>	<input type="checkbox"/>
9.	Identify appropriate times and methods for expediting project work.	<input type="checkbox"/>	<input type="checkbox"/>
10.	Provide a basis for monitoring project technical, time and cost performance.	<input type="checkbox"/>	<input type="checkbox"/>

4.292 **Advantages of Networking:** Networks are not used for planning purposes as often as are Task Lists, Deliverables Charts and Bar Charts. This is because they are not as easily understood; nor in common practice. However, their advantages for planning should be carefully considered. The greatest strength of networks, as tools for planning, is their demand for careful analysis and definition in planning. They require that the planner define discrete tasks; specify actual deliverables; detail methodologies; and accurately (or, as accurately as possible) estimate time and resource requirements. Networks are useful because they demand some precision in planning. As a consequence they also permit accurate prediction of timing, resource requirements, lag time, down time, bottlenecks in scheduling and other critical management considerations.

What are the advantages of networking?

4.293 **Disadvantages of Networking:** But those strengths are also the greatest weaknesses of networks as planning tools. We have said many times before that there is a large element of uncertainty in R&D work. How can a planner be as accurate and precise as demanded by networking tools, in a work environment which is, by definition, uncertain? In actual fact, many R&D planners who have used networking tools have gotten into some difficulties because the uncertain numbers they plugged into the networks, suggested more certainty than was really present in the R&D environment. Thus their beautiful plans lent an unrealistic aura of confidence and predictability in the management of R&D. Needless to say, such experiences yield only disappointment, when planned outcomes are not realized.

What are the disadvantages of networking?

4.294(a) Challenge for R&D Planners: The challenge for all of us R&D planners, is to predict as certainly as possible—using the strongest tools available. Then, we must monitor and control actual work performance against those plans so that we can detect, as early as possible, when performance is deviating significantly from what was predicted. When that occurs, we must remain flexible enough as managers to make adjustments—either in performance, resources, or plans.

4.294(b) In other words, we would encourage the use of networks, where they apply. But only under conditions where good monitoring measures are in place; and where managers are willing and able to control R&D plans and performance.

3. Application of Planning

4.31 Introduction: In the previous two sections we introduced planning at the strategic and project levels; and we explained the operation of a variety of planning tools. Now it remains to wrap-up this discussion of planning by summarizing some of the most critical aspects and describing how planning tools are applied. Let us start by reviewing the principal elements of any planning effort: tasks, time and costs.

4.32 Project Tasks: Without all the other trappings, a planning tool which presented only the project tasks is very useful. Of course, that is basically what we have with the Task List. It helps project staff and RDI managers (who generally work outside the confines of the project) understand the logical sequence of technical operations and deliverables which must be expected from any project. In a technical sense, it permits a comparison of R&D activities—whether they comprise tasks of a single R&D project, projects in a programme portfolio, or sectoral elements of a national R&D strategic plan.

4.331 Time: The addition of time to the list of R&D tasks permits planners at all levels to begin controlling not only the sequence of

tasks, but their duration as well. Time is one factor which suffers most in R&D work. And, too often, R&D managers simply disregard time as a factor in planning because they figure it is totally unpredictable anyway.

4.332 But, time is money! Whether time is spent by machines or people, costs are charged to some account. Planning through the use of tools like networks and bar charts helps research managers take responsibility for time and, ultimately, costs.

What is meant by "time is money"?

4.333 At the beginning of this chapter on planning we said that the unpredictable nature of R&D does not mitigate the importance of planning. That is particularly true where the time required for, and available to, R&D is concerned. Who can say how long it will take to invent some new technology; or even adapt an imported one for local applications? But, to avoid such predictions simply because they are difficult is to virtually ensure that the R&D operation will, sooner or later, encounter cost problems which threaten its very existence.

4.341 **Costs: Costs!** The bottom-line for many managers. And, a necessary evil for dedicated researchers who would rather concern themselves with the technical output of their efforts. Time certainly is a contributor to costs—after all we speak of person-days in planning labour costs (and "days" is a unit of time).

4.342 But there are many other sources of costs for any given R&D effort. Materials, equipment, buildings and specialized facilities, test animals, travel, utilities, information, and so on, and so on, and so on. . . . The trick for research managers is to reliably anticipate the costs of each task in each R&D project; aggregate these costs so that predictions can be made about the costs of R&D programmes; and aggregate programme costs so that managers can estimate the costs of R&D for the institute as a whole.

4.343 The networks we have been drawing help us do that. At least, they break the project down into discernible parts so that we may more easily guess what real costs will be. But they also provide

the time information which, as we have already seen, contributes to costs.

4.344 Therefore, networks help us get started in estimating the costs of projects. But they are not the whole picture, by any means. To continue our R&D planning in the cost domain, we need to engage in a planning process called “budgeting.” That will be the subject of a later chapter. Suffice it for now to note that these planning networks are a first, and very useful, step in the cost planning process.

4.345 In sum, tasks, time and costs are the three principal elements of any planning exercise. Planners try to anticipate what will be done; for how long; at what cost? These same factors comprise the principal elements of monitoring and control, as well. After planning, good managers engage in monitoring technical performance (tasks), time performance, and cost performance. When their indicators show that any of these may deviate from what was anticipated (planned), then they exert some control (change the methods, vary the resources, or even replan.) In other words, plans lay the groundwork for managing the actual performance—hence results—of R&D.

4.346 Another unique application of plans in R&D work is in project or programme selection. Managers can use planning techniques to be certain that the projects or programmes for which they choose to provide resources have a fair chance of succeeding. In other words, they use planning to ascertain that chosen projects or programmes match the technical capabilities of the RDI; are consistent with development priorities of the country; and fulfill a significant need of their proposed end-users.

4.351 **Plans Aid Project Selection:** A glance back at Figure 1, will show that we are progressing with our bottom-up planning strategy. We have discussed scheduling; resources will be discussed later in “budgeting”; and it is time to show the relationship between project planning and project selection. Selection is an important process because it determines the RDI’s success in fulfilling its goals.

PLAN	MONITOR & CONTROL
Tasks	Technical Performance
Time	Schedule Performance
Costs	Financial Performanace

Figure 1 is on page 98

One principal use of R&D project, or programme, plans is for control purposes.

4.352 The need for R&D is constantly increasing while financial resources for it are dwindling. So how does the management of an RDI decide which projects to continue, discontinue, or simply modify in resource allocation? There has to be some approach which is more useful than across-the-board reductions in programmes.

But before that, such plans are very useful for the purpose of selecting R&D projects and developing the RDI portfolio.

4.353 Omission of projects, for either lack of urgency or potential, should be considered. Selected areas of the research programme should be eliminated and the funding diverted to those R&D programmes which best satisfy the economic needs of the country. But the problem is further complicated by the need to introduce new projects into the R&D programmes as new ideas and opportunities arise.

How are R&D projects selected in your RDI?

4.354 The effect of distributing inadequate funds across the total number of desired projects runs the risk of dooming all of them to failure. The elimination of a single project, of course, removes any returns which that project might bring to the overall programme. However, this latter strategy does not weaken the entire R&D effort.

- ☐ Director's favourite
- ☐ Researchers' choices
- ☐ Cheapest projects
- ☐ Quickest projects
- ☐ Technical feasibility
- ☐ Merits of results
- ☐ Combination of these

4.355 Project plans provide all the information needed for RDI managers to select those projects which will comprise the RDI's R&D portfolio: purpose and objectives; anticipated results; R&D tasks and methodologies; scheduling; costs and other resource requirements.

4.356 These information are frequently used for three project selection techniques: capital budgeting, cost prediction and scoring and ranking techniques.

4.361 **Capital Budgeting Techniques:** This technique for choosing among alternative R&D projects comes from the private sector. Indeed, it is practiced most often by RDIs which still have strong ties to the private sector (like RDIs which are funded and overseen by associations of manufacturers; those which are proprietary arms of manufacturers; or those which are engaged in large volumes of contracted R&D).

Does potential profit from the technological outcomes of R&D ever figure into project selection in your RDI?

Why, or why not?

4.362 The **capital budgeting technique** is based on the standard rate-of-return on investment.

However, it is modified by the inclusion of some risk dimension, like probability of commercial and technical success. All these factors are treated quantitatively and then proposed projects are ranked for final selection.

Should the output of RDIs ever be considered from the standpoint of their commercial value?

Why, or why not?

4.363 We do not recommend that you study this technique in any detail because: (1) it is not particularly well suited for R&D projects; and (2) it is not particularly well suited for government sponsored RDIs.

4.364 Principal weaknesses in these techniques are that they assume the same rate-of-return over the life of the project; the earning from the project can be reinvested at the same rate; and the same level of risk exists through the life of the project. Nothing is further from the truth, particularly with R&D projects.

Why is it so difficult to anticipate the potential revenues from sales of new technologies?

4.365 Therefore, we recommend that capital budgeting techniques not be used for R&D project selection, despite the fact that they are widely used in some R&D sectors (like chemicals).

4.371 **Cost Prediction Formulas:** These formulas use expected revenues from sales of the new technology to determine the value of investment in R&D. They too, include a certainty factor—usually the probability that the cost estimate is correct. Underlying these approaches is the premise that historical relations exist between the cost of R&D and the total sales from the product of R&D.

4.372 This assumption is questionable in most Third World settings. While certainly some historical relations must exist between these factors, there is considerable question whether they have been recorded reliably—and, further, whether such relationships reflect sufficient stability over time to permit accurate cost prediction.

4.373 Another problem with this approach is the assumption inherent in it that derived technologies will find their way into a retail

economy. This may be true in many cases. But in many others it may not. For example, in a government-sponsored RDI, the benefits of R&D are supposed to accrue to the public at large, without the disincentives of a market economy.

4.374 In such cases "sales" value of R&D must be reinterpreted in terms of other economic indicators—like productivity, income, employment, and the like. Then, if "costs" of the R&D can be predicted reliably, the cost prediction formula becomes a sound basis for project selection.

When is the "cost prediction formula" a sound basis for R&D project selection in a Third World RDI? Explain!

4.375 Sometimes the variable "sales" is easier to estimate reliably than R&D costs. In such cases it is tempting to try to predict costs from estimates of sales. However, to make accurate sales estimates, one needs to know the performance of the product from R&D information that is seldom known until the project is completed. Therefore, this is another technique, which while frequently used, must be applied with full awareness of the potentially faulty assumption inherent in it.

4.381 **Scoring and Ranking Techniques:** Scoring and ranking criteria are the most commonly used methods of project selection. They usually consist of simply ranking projects according to some list of criteria, and then selecting projects from the top to the bottom of the ranking until some cutoff point in expenditure is reached.

Does your RDI ever use these criteria in comparing projects?

4.382 The criteria may include product life, patentability, market dimensions, financial criteria like cost and personnel requirements. Scoring and ranking techniques are preferable to capital budgeting or cost prediction ones because the latter involve too much uncertainty. Scoring and ranking techniques are particularly useful if they incorporate some resource allocation dimensions among the selection criteria. A typical quantitative relationship used in this technique is:

What criteria are used in your RDI?

Replace some of these with your own criteria in the formula which appears on the next page.

$$\text{Score} = \frac{\text{Patent rating} + \text{Sales rating} + \text{Technology rating}}{\text{Expected project cost: Total R\&D allocation}}$$

4.383 The ratings used in the top of the equation are independently generated. Each is represented by some number determined by a planner who has the kind of knowledge required to make valid and reliable judgments about projects on the appropriate criteria. Some of the criteria may relate to the RDI's mission and overall capabilities. Probably senior managers are best qualified to make such judgments. But others may relate to the science required for the proposed projects. In these cases, researchers are probably better-qualified to generate such ratings.

Then think of a real project and apply some scale values to the formula. Work it through in comparison to some other project and see if you agree with the numeric outcomes.

4.384 For each rating a quantitative scale is developed by equating the numbers of the scale to more-or-less discrete definitions of the criteria. **Figure 8**, on the next page, shows one example.

4.385 **Figure 8** shows how a quantitative value, in this case representing "probability of technical success", can be derived to fit any project selection, scoring and ranking process. This measure provides a 5-step scale for assessing a proposed R&D project's likelihood of success—based on technical factors. Other factors could be done the same way.

4.386 To use the scale, a planner would rate each proposed project on five criteria which comprise probability of technical success. If, for example, the planner felt that the proposed product of R&D was "well known and backed by readily available technical information," then it would be assigned a value of 0.9 on the first criterion. Or, a value representing slightly less than that could be assigned (0.7) if the product class is known but only slightly defined, etc. This kind of assessment is made for the proposed project, on each dimension of technical success.

Figure 8. Scale for Developing a Project Rating on Probability of Technical Success

Item	Criterion Description	0.9	0.7	0.5	0.3	0.1
1	Technical information	Product is known or well defined		Application needs are well defined but product class is not well known		Exploratory project not well defined
2	Engineering	Process generally conventional, product will likely fit into existing facilities		Some novel aspects to processes, modification of facilities probably needed		Sophisticated process controls needed and/or major construction
3	Technical difficulty	Only confirmatory lab work needed		Moderate amount of bench work, testing and pilot scale work		Extensive research, application testing and /or pilot plant needed
4	Legal	Product has dominant patent position (or exclusive license) or is likely to achieve such a position		Field relatively free of dominant patents, or can probably get license		Someone has dominant patent position, would not be able to get license
5	Personnel	Research people are leaders in field; experienced support available		People are on par with those elsewhere		People are newcomers in field where others have established expertise

Note: These specific criteria are only examples; others should be selected for their relevance to the project in question.

4.387 It is the kind of evaluation work, for planning purposes, which is best done by the people who are most knowledgeable about the R&D, the proposed projects, the RDI's mission, and other pertinent aspects. That is why we encourage RDI managers to use a bottom-up, participative, planning strategy. Can you imagine, for example, how poorly this particular probability-of-technical-success scale would be applied by a senior RDI manager who was not thoroughly familiar with the technical aspects of all the R&D projects they were asked to rate? It could lead to very poor selections for the RDI's portfolio, and ultimately jeopardize the RDI's capability for achievement.

APPLYING SCALING AND RATING TECHNIQUES:

1. *List important criteria for selecting projects in your RDI.*
2. *Develop scale definitions for one of the most important criteria.*

4.388 A more effective planning strategy would require that researchers apply scales like this to each project. But later in the selection process, senior managers combine the scales for all the criterion dimensions in a quantitative evaluation and ranking process. Of course, they also retain the authority and responsibility to select projects on the basis of such derived scores, or any other criteria which they deem appropriate. One set of criteria about which they will be particularly concerned is RDI resources: time, money, materials, facilities, and so on.

4.389 This brings us back to planning. Project selection and development of the RDI research and development portfolio is a logical outgrowth of planning. It is one of those vital R&D management functions which is dramatically improved when the RDI adopts effective planning practices.

4.391 **RDI Planning Certainty:** Both planning and project and programme selection involve the process of estimating the outcomes of some R&D practice. The value of planning and project selection, therefore, depends in large part on the quality of RDI managers' forecasts about R&D outcomes. Can research costs be accurately predicted? If so, then why do we most often encounter research cost overruns?

4.392 Can we anticipate the characteristics of R&D results, if not the products themselves? Admittedly, these are the challenges of planning and budgeting in R&D. A good RDI planner is like a good wizard—there is regimen and discipline to their work. But at the same time, there is a strong element of intuition and (frequently unjustified) confidence. Perhaps that is why planning is so difficult for people who are disciplined by the sciences. They have been taught to rely, perhaps too heavily, on the logic of what is known, and what is certain.

4.393 The outcomes of R&D are not certain. Of that we can be sure. In fact, where financial management, and planning, are concerned, we can develop a linear relationship between the types of R&D, and planning certainty. Figure 9 shows this relationship:

3. *Combine your scale with those of 3 other participants; develop a rating form like the one in Figure 8.*
4. *Now apply the rating form to a fictitious project. Each of you should rate the project privately.*
5. *Then compare your ratings and discuss the scaling and rating process for project selection.*
6. *What are its advantages and disadvantages? What is needed in your RDI for this selection process to work well?*

Can planning be used to reduce actual R&D project costs, and cost overruns?

Can it be used to expedite projects?

Can it be used to improve technical work?

Explain your answers!

Figure 9. Types of R&D in Relationship to Financial Planning Certainty

Types of Research		Research Goal	Planning Certainty
1.	Basic Research	Find any new knowledge	High degree of uncertainty in financial planning as well as technical outcomes
2.	Applied Research	How to use new knowledge	Less uncertainty in financial planning
3.	Development Research	Transfer of new knowledge to application site	Less uncertainty; overall cost per period is usually greater than for either basic or applied research

4.394 Experienced RDI planners have four axioms which apply to financial and technical planning:

1. Effort on a project (input) can be predicted with some degree of accuracy; but R&D results (output) cannot.
2. The R&D budget is likely to be accurate in the aggregate, but not in detail.
3. Research programme budgets are accurate in the short run only.
4. Plans, or any other attempt to forecast in an RDI, must allow for programme and decision flexibility.

If R&D is so uncertain, then why do we bother to develop plans for it?

Aren't we only getting ourselves up to demonstrate the futility of planning accurately? Explain!

4.395 So the point is: **Plan, but with realistic expectations of its accuracy. Plan, but with tolerance for the certain need to change those plans. Plan, but recognize that its results are far poorer guarantors of R&D success, than the planning process itself.**

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*MANAGEMENT MANUAL FOR PRODUCTIVE R&D:
R&D STRATEGIC AND PROJECT PLANNING AND BUDGETING*

CHAPTER V
BUDGETING

BUDGETING

Training Objectives

By the end of this chapter, the participants will be able to:

-
1. Define budgeting and explain its relationship to R&D planning.
 2. Outline the principal purposes and uses of budgeting.
 3. Explain the roles of strategic managers, project managers and support staff in R&D budgeting.
 4. Differentiate among seven budget allocation and formulation approaches. Explain their strengths and weaknesses.
 5. Explain the role of a Task List in developing an R&D project, or programme, budget.
 6. Identify the principal categories of costs for any R&D effort.
 7. Calculate labour costs on a hypothetical R&D project.
 8. Calculate special services, equipment, supplies, travel and other R&D project costs.
 9. Explain the role of accountants in budgeting R&D.
 10. Explain the differences between direct and indirect costs on an R&D project, or programme.
 11. Define overhead costs and explain how they are derived.
 12. Aggregate project budgets into an RDI budget.
 13. Interpret the meaning of an RDI budget.
 14. Explain what budget balance means; and how to get it.
 15. Design a budget presentation and approval process.
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BUDGETING

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This material should be covered in about three sessions, of fairly equal duration. Exercises at the end of each part can usefully serve as between-session "homework."

CHAPTER V

BUDGETING

The total appropriation for R&D is generally determined by government's more-or-less educated view of how much money is needed to produce technologies that will solve the country's development problems. Too often this results from something less than an educated view. Therefore the challenge for RDI managers is to: (1) learn to educate government about the relative importance and role of R&D in national development; and (2) learn to plan and control the use of finances which are available for research and development.

1. Role of Budgeting in R&D

5.111 **Introduction:** Budgeting can be seen as a detailed and time-consuming task which appeals to the kinds of people who are only content with facts known; whose comforts originate with the order and reason in life; and whose greatest unease comes; from surprise results or no results at all. How many of these people make a career out of R&D; how many of them learn the disciplines of scientific inquiry?

5.112 Or, budgeting can be seen as a principal instrument for leveraging vital resources in support of the R&D enterprise; and for ensuring that the scientific pursuit of what is unknown progresses in an orderly and predictable manner. This latter vision of budgeting suggests that it belongs in the

What is budgeting in an RDI?

arsenals of all researchers, project leaders, research division heads and senior RDI managers.

5.113 The concept of budgeting is the same as that described in the previous chapter on planning—because budgeting is a planning process. It is the process of figuring out how much money will be required to accomplish R&D. How much is needed for each element of an RDI, an R&D programme, or tasks in a particular project. It even involves time. Budgeters (planners who plan money) frequently estimate a schedule of costs and payments.

How are budgeting and planning related?

5.114 In most countries, the process of budgeting in an RDI is closely integrated with budgeting systems used throughout government. Many RDIs are required to adhere to government budgeting standards and methods. This makes for more budgetary compatibility throughout government. Hence government is better able to monitor and control all its costs.

5.115 But at the same time, it limits an individual RDI's flexibility in financial planning and control. Therefore, RDI budgeters need to be very clever in balancing the financial planning and control requirements of government with the special needs and management characteristics of the RDI.

5.116 This chapter on budgeting is divided into three parts. The first introduces and defines the concept of budgeting. It overviews budgetary processes and explains their relationship to financial resource allocation. The second part details how a budget is set up. It converts the fictitious UHF Radio Receiver project which we planned in the planning chapter, to a project budget. In this part the reader will walk through a standard budgeting process, step-by-step. In the third part, important budgeting concepts are reviewed and the whole chapter is summarized.

5.121 **Definition: Budgeting is the process of anticipating the financial requirements for R&D.** It is very much like the process of anticipating the scientific tasks required to complete an R&D project; the materials that will be needed; the

instrumentation; the specialized human skills. In other words, budgeting is planning — only, in the exclusive domain of RDI finance. Everything we have learned about the planning process will greatly enhance the effectiveness of RDI project and programme budgeting.

5.122(a) Budgeting is Planning: Any discussion of budgeting must begin with the term “planning”. In some ways, budgeting is the most conspicuous type of planning the RDI manager conducts simply because money is the single resource which is common to all other commodities and processes in the RDI.

Budgeting, scheduling, and figuring out the technical tasks in an R&D project, all have something in common. What is it?

5.122(b) Everyone in an RDI has in common with everyone else, the need for money — regardless of the technical or administrative specialties in which they are engaged. Consequently there is a lot of demand for money; demand leads to competition; and the whole system impinges on managers’ abilities to make tough financial decisions. It is easy to see why sound planning is required in the financial arena.

5.131 Purposes of Budgeting: The research budget is a planning device. Its main role is to express scientific and operating plans in financial terms. By doing so, it allows RDI managers to plan, direct, and guide research and development work. Managers exercise these functions by controlling the amount of money available for each segment and task of the research project, the research programme, and for the RDI as a whole. Budgeting assists R&D planning in several specific ways:

How does budgeting relate to the overall performance of the R&D programme, or project?

1. It encourages concrete programme planning.
2. It stimulates programme coordination throughout the RDI.
3. It generates programme control points.
4. It facilitates periodic programme reviews —leading to more planning.

How does it help manage the R&D?

5.132(a) **Concrete Planning:** The mere fact that researchers at all levels in the RDI must carefully plan their future activities makes them more aware of the need for progress toward a goal, and the cost of this progress. Their estimates—no matter how crude—give them guidelines to know when they are conducting their work successfully, and when some adjustments must be made. Such careful planning throughout the RDI increases everyone's confidence in the research process.

Do managers at all levels of your RDI plan their activities?

5.132(b) In the process of developing periodic budgets, research managers are forced to plan their programmes concretely—i.e., as factually as possible. Budgeting requires very deliberate and careful planning and scheduling of all project tasks and resources. It helps orient the staff to the nature of the technical problems to be faced; and it helps relate the project tasks to the whole technical programme of the RDI. Budgeting forces managers to:

How closely do their plans relate to what really happens in the RDI?

1. Check detailed technical plans
2. Avoid crisis management.
3. Avoid duplication of effort.
4. Estimate realistic times and costs.

Are all these plans coordinated and rationalized to enhance mutual goal accomplishment? How is it done?

5.132(c) The RDI budget is the only planning device that annually aggregates the technical, financial and other plans of individual R&D projects and programmes. It, therefore, helps managers foresee the total impact of all RDI resources. This makes everyone in the RDI more aware of their purpose, the RDI goals, and each division and department's role in achieving them.

How does budgeting force R&D technical people to plan concretely?

5.133(a) **R&D Programme Coordination:** RDI budgeting helps coordinate research and development programmes throughout the institute. This is because it forces research managers to make critical choices and selections among alternatives for resource expenditure in all programmes and departments. Hence, they must know about all activities and their relationship to RDI goals.

What happens if the plans for one RDI functional unit are not coordinated with those of another?

5.133(b) As a result, the budgeting exercise forces RDI managers to:

Give an example!

1. Balance R&D activities within programmes and within the RDI, as a whole.
2. Encourage the exchange of programme and administrative information between, and among, all units in the RDI organization.
3. Develop and understand the relationship between current (short-range) and future (long-range) plans of the institute.

How does budgeting help coordinate R&D programmes throughout the RDI?

5.134(a) **Programme Control Points:** The budget is useful for controlling money, as well as planning it. It tells not only how much money is needed for a particular phase of R&D activity, but how much should have been spent up to that time. It relates expenditures to technical productivity so that managers can tell how much each technical phase should cost. Therefore, it establishes checkpoints for financial control.

5.134(b) Another control point is total expenditure to date. Many RDIs arbitrarily select a certain percentage of total expenditure to review project progress and resources needed to complete the project. Such a time for review may vary from RDI to RDI. It could be 50 percent, 75 percent, or even 105 percent. But the point is that expenditure, itself, forces review and control of the project.

How does a budget establish checkpoints for evaluating R&D project progress?

5.134(c) After the initial planning period, the budget helps control research by providing control points and forcing reviews of projects; keeping research managers money conscious; and keeping total research expense in line with budgeted expense.

5.135(a) **Periodic Programme Reviews:** The R&D budget tells how much money will be available for each task in the research process—well before the research is even started. In that sense, the R&D budget helps control expenses before they are incurred, rather than after the fact. That is why it is so useful as a planning tool.

If all the project money is spent, does that mean that all technical work has been successfully completed?

5.135(b) But, as with other plans, reality frequently deviates from what was expected. Therefore, plans must be reviewed, and revised. Similarly, the budget forces the research manager to review R&D progress and financial needs and allocations. This has two particularly beneficial effects:

1. The research programme cannot proceed haphazardly, or undirected, for long periods of time; and,
2. Researchers are encouraged to not only control the progress of their work, but also to show and review it with their colleagues, frequently.

How can a budget help control technical progress on R&D projects?

How can a budget stimulate communication in an RDI?

5.135(c) At budget reviews, managers must justify requests for new project funds, or continued financial support of planned R&D tasks. Their justification rests on proving the productivity of work done, as well as the promise of work to do. This periodic, task-by-task review keeps the R&D focused on desired results.

5.135(d) Research managers are also reluctant to request continued financial support for R&D unless their efforts to date have been successful; and their anticipated efforts hold great promise for more success. Thus, the periodic reviews of R&D budgets contribute to more careful research planning and higher research productivity.

How can budgeting enhance R&D productivity?

5.141(a) **Level-of-effort:** The budget summarizes a plan which declares that, "These people will work on this project, for this long, and spend this amount of money." Thus a budget predicts the level-of-effort authorized for the project. This is the effort available and permitted—not necessarily sufficient—to complete the project.

Which is easier to predict—the cost of a project, or its results? Why?

5.141(b) Who really knows what level-of-effort is required to complete the project; no one can predict exact project outcomes. There is no output schedule with which the budget can be compared. Therefore, the budget cannot set standards for measuring the efficiency of R&D work. The budget measures planned effort, not achieved results of R&D.

What is "level-of-effort"

5.142 R&D Budgetary Accuracy: In R&D budgeting, it is important to remember the same four principles mentioned earlier during our discussion of planning:

1. The level-of-effort, or amount of resources, for a project can be predicted; but the project results cannot.
2. The RDI budget can be accurate, in aggregate; however, detailed programme or project budgets are less likely to be accurate.
3. R&D programme or project budgets are accurate only in the short run.
4. R&D budgets must be flexible, in order to adapt to the changing requirements of R&D.

If it is so difficult to accurately anticipate R&D costs, why bother?

5.143(a) Aggregate Accuracy: What do we mean that an RDI aggregate budget can be more accurate than a single R&D project budget? This is an important concept because it means that at the RDI level, financial management is a fairly static process. A fixed amount of money is granted to the RDI—and annual expenditures will not exceed that amount.

Which is liable to be more accurate—the sum of all RDI planned expenditure, or the sum of planned expenditures for a single R&D project? Why?

5.143(b) But at the project-level, what's fixed? As we saw in the planning chapter, there is so much uncertainty in the R&D process that anticipated expenditures must, frequently and necessarily, change.

5.143(c) Let us look at an example. Assume we have an RDI with three R&D projects (we will keep it simple for the sake of the example). Projects A, B, and C are expected to cost the RDI a total of \$30,000 U.S. They are budgeted as follows:

	A	B	C	TOTAL
Budgeted	\$5,000	10,000	15,000	\$30,000

5.143(d) Assume government gives this RDI the requested \$30,000 and then the RDI commences all three projects. But, by the end of the fiscal year,

actual expenditures on each project do not equal the planned (budgeted) costs. Here is what the "actuals" look like at the end of the fiscal year:

	A	B	C	TOTAL
Actuals	\$5,500	8,500	16,000	\$30,000

5.143(e) Let us now look at the amount of error in these estimates. Error is calculated by dividing the difference between budgeted and actual costs, by the budgeted cost. It yields an error in terms of a proportion of the budgeted cost:

	A	B	C	TOTAL
Budgeted	\$5,000	10,000	15,000	\$30,000
Actuals	<u>5,500</u>	<u>8,500</u>	<u>16,000</u>	<u>30,000</u>
Difference	- 500	1,500	-1,000	-0-
Error	10%	15%	7%	-0-

5.143(f) Notice that while there is considerable error in the budgets for each project, there is no error for the RDI as a whole. Notice, too that the minus sign in the "difference" row tells you the direction of the error. In this case, Projects A and C suffered cost overruns. But Project B managed to come in with less cost than expected. That meant that the RDI financial controller was able to pay for the overruns on A and C, with the balance left for B.

5.143(g) All three projects experienced budget error ranging from 7-15. But that notwithstanding, the RDI aggregate budget suffered no error at all. This exemplifies what we mean when we say that aggregate RDI budgets are more accurate than disaggregated R&D project budgets.

5.143(h) It also exemplifies what we mean when we say that far more flexibility in the management of finances exists at the project level. It is not often that government will tolerate an RDI cost overrun. Government simply cannot incur this kind of debt. But, as in this example, the flexibility often exists for RDI managers to vary their project plans and expenditures in order to accommodate individual project error, within the constraints of the total RDI budget.

How does the issue of "flexibility" in financial management relate to the difference in accuracy, between RDI aggregate, and R&D project budgets?

5.143(i) Such flexibility is not a license for planners to budget inaccurately. Not all budget errors will compensate for each other as nicely as has our fictitious example. Flexibility is available and useful for managing R&D finances. However it must be wielded with care and considerable financial discipline.

5.143(j) One last point about this example. You will notice that in the "error" row we did not use the minus signs to indicate the direction of the error. That is because we are trying to make another point—namely, an error is an error! In budgeting, our intent is to predict as accurately as possible. An inaccurate prediction is an error—regardless of its net impact on the aggregate budget. While some errors which yield a balance may offset errors which yield a deficit, all of them are errors—and therefore, we need to improve our methods of estimating costs in order to increase budgeting accuracy.

5.143(k) The example given above works out very nicely because positive and negative errors in project budgeting cancel each other in the aggregate. But the same principle of aggregate accuracy obtains even when all three projects experience cost overruns. Here, for example, are the same three projects:

	A	B	C	TOTAL
Budgeted	\$5,000	10,000	15,000	\$30,000
Actuals	<u>5,500</u>	<u>11,500</u>	<u>16,000</u>	<u>33,000</u>
Difference	- 500	-1,500	-1,000	3,000
Error	10%	15%	7%	10%

5.143(l) The amount of the cost overruns for all projects sums to \$3,000; that is the aggregate overrun. Logic would suggest that the amount of error in project budgets also aggregates through a summing process. That would yield an aggregate error of $10\% + 15\% + 7\% = 32\%$. But the math simply does not work that way. The principle of aggregate accuracy indicates that the error in RDI budget over the same period is only 10%. In fact, project budgetary errors are equal or greater than RDI aggregate error in two thirds of the projects. This is what we mean by aggregate accuracy.

5.144(a) Budgetary Reviews: Detailed costs of R&D programmes, or projects are less stable, predictable or accurate than aggregate RDI budgets. This is because the technical fluctuations, and requirements of a project vary widely, and frequently.

5.144(b) Sometimes more, or less, personnel time is needed; more, or less, material is needed; and even more, or less, down-time (when no one is working on the project) is needed. Some projects unexpectedly show promising results and are expanded. Others have the opposite results, with the opposite decision by management. Such fluctuations in the project require changes in the level-of-effort. Hence, budgetary reviews and replanning are necessary throughout the course of R&D.

Describe the conditions under which budgets have been reviewed and replanned in your RDI.

5.145(a) Short-run Accuracy: Related reasoning explains why R&D budgets are most accurate in the short-run. That is why many RDIs review and revise their project and programme budgets as often as quarterly (every three months). Such a level-of-effort for budgeting alone would probably justify the development of a planning and control unit within the RDI.

Which is liable to be more accurate—the anticipated costs of a project next year, or its total cost over the next five years?

5.145(b) Many RDIs adjust budgets semiannually (every six months) although total allocations to the RDI are most likely made by the government on an annual basis. The farther into the future a project budget extends, the less accurate its details. The utility of long-range budgeting is primarily to insure concrete thinking about long-range goals.

Explain!

Is it as important to be accurate in the long-term, as it is in the short-term?

Why, or why not?

5.146(a) Budgetary Flexibility: The word “flexibility” arises again. Remember, it was used in the introductory paragraphs about organization of an RDI; and again, in the early discussions of planning. It seems to be key to R&D budgeting, as well.

5.146(b) All of the earlier comments about constraints to R&D budgeting lead to the need for budgeting flexibility. R&D budgets are merely estimates—to be used as guides, not rigid limitations. And it is very important that they be

Why is “flexibility” required in R&D budgeting?

accompanied with processes for changing them when necessary.

5.146(c) In this sense, "flexibility" means the ability to make management decisions either about the progress and performance of R&D projects and programmes, or the budgets and schedules planned for them. To repeat an earlier admonition: "flexibility" must not be construed as a license to manage finances loosely, or budget without care and accuracy.

5.146(d) Some RDIs avoid flexible financial management techniques because they fear that the researchers' worry about costs will get in the way of good research. Others prefer strict budgetary limitations because they require more definite fore-thought about research objectives and techniques.

5.146(e) In most RDIs, budgets are more flexible for basic research projects, than they are for development studies. In the latter, budgets may be used (with care) as standards for assessing technical progress on the project. But that would be a very big mistake in basic research projects.

Why must there be more flexibility in budgets for basic research, than for applied research?

5.146(f) Current practices in RDIs suggest two general guides for improving budgetary flexibility:

1. Do not budget in more detail than you intend to control; and,
2. Use the simplest, least burdensome, and most flexible planning and control systems.

5.151 **Two Levels of Budgeting:** In all RDIs financial planning and control should take place at two levels. They parallel the two levels of planning discussed earlier: strategic planning and operational planning.

5.152 At the highest level, budgets are used to inform the government of financial needs for R&D in the foreseeable future. Budgeting at this level usually leads to the annual allocation of finances to the RDI, by the government.

What are the two levels of budgeting in an RDI? How are they different?

5.153 At the second level, budgets are used to control the allocation and expenditure of finances for research tasks and activities within each R&D programme and project. Interestingly, the emphases in these two levels of budget activity differ. At the strategic level, the budget is developed (usually) once a year and it remains fairly stable. At the operational level, however, budgets are reviewed at least quarterly and frequently revised as often.

What is the principal use of strategic-level budgets?

5.154 At the strategic level, budgets are used to acquire finances from government, whereas at the operational level, they are used to anticipate and control expenditures. At the strategic level, there is far more budgetary accuracy and stability. At the operational level, costs change as technical demands in the project change.

And what is it for operational-level financial planners?

5.155 But, there is a very important relationship between these two levels of budgetary activity. Hopefully, the annual allocation matches, to some degree, the operational need for research finances.

5.156 Such a match is only achieved if the RDI budget which accompanies the annual request for funds from the government is based upon results from budgetary exercises at the operational level. In other words, operational-level budgeting provides a foundation on which managers can build the RDI budget.

What is the relationship between strategic and operational budgets?

5.157 This is a relationship which is too often overlooked by RDI managers. Most RDIs expend large amounts of effort on the annual, institute-wide, budgeting exercise for the government submission. But few of them also operate an internal, operational-level financial planning system. If they did, their annual exercise would be far easier; but more significantly, their control over research costs and financial resources would be far more efficient and effective.

What is the purpose of budgeting in your RDI?

5.161 **Role of RDI Managers:** The role of various research managers in budgeting depends, in large part, on the organization of the RDI and the predominant style of management. In a highly centralized RDI, for example, research budgeting decisions are usually made by senior managers

Does it occur at strategic, operational, or both levels?

who may presume too much knowledge about the specific resource requirements of projects in the RDI's portfolio.

5.162 The pressures for centralized budgeting are clear. In the first place, the government expects the RDI director to take responsibility for expenditure of government funds. Naturally this expectation leads many RDI directors to jealously guard the prerogatives and processes of budgeting.

5.163 Further, while researchers may complain that they have too little control over financial resources for their own projects, they, at the same time, frequently complain when management responsibilities like budgeting interfere with their time available for research activities.

5.164 That notwithstanding, it is also clear that effective budgeting and financial control in an RDI depends on the coordinated efforts of managers at all levels in the institute. Senior managers cannot know enough either about the technical progress on each project, or about the technical requirements for continued research, to project operational needs for financial resources.

5.165 Further, they do not have the time to develop this knowledge—if they are fully engaged in another strategic-level budgeting activity which is exclusively their responsibility. In the statement which opened this discussion of budgeting we mentioned that RDI senior managers must learn to educate government about the role of R&D in national development. That is one of the RDI director's most important budgetary responsibilities. After all, their success in this activity has a most direct bearing on the annual government appropriation for R&D in the institute.

5.166 Let us take a break from this material and discuss its meaning for our own RDIs.

What are the roles of senior RDI managers, and R&D project leaders in budgeting in your RDI?

Exercise 1: Analysis of Budgeting Roles in RDIs

Let us discuss the issues raised about budgeting in the context of our own RDIs. For this purpose, divide yourselves into small discussion groups of 3–5 participants.

Some questions appear on the next page. Each of them is based on the issues already raised about budgeting. The group's task is to discuss each one. Notice that the major point raised by each question is noted in parentheses after the question.

For this exercise, each discussant will present their answer to the first question in 1–2 minutes. After each one has explained their answer to the question, the group will discuss particularly interesting similarities or differences among their answers (also for 1–2 minutes). The group will emphasize comparisons of their answers to comments made in this study material. Then they will proceed to the second question, and so on until all questions have been answered.

[Instructor(s): You may wish to circulate among the discussions and note particularly interesting points for consideration by the whole group after the small group period. Listen for discussions which are having a particularly difficult time applying the ideas presented in the study material. Participate when, and where, necessary in order to help the discussants comprehend the value of budgeting in the RDI. You may wish to ask particular people to present particular ideas in plenary. Perhaps you would like to pick one person to present a summary of discussions in their group—for each of the questions. That would serve as a good summary for the whole group.]

The eleven questions follow:

1. Does your RDI have an annual, aggregate budget for all operations? Does it have a separate budget for each R&D programme; and/or for each R&D project? (**Two levels of budgeting**)
 2. How often during a single year, does the RDI's total annual allocation from government change? (**Accurate aggregate budgets**)
 3. How often during a single year, does the individual budget for a single R&D project change? (**Inaccurate detailed programme budgets**)
 4. Are R&D project budgets in the RDI based on the aggregate institute budget? Or is the annual RDI budget based on individual project budgets? (**Relationship between RDI and project budgets**)
 5. **What** role do research project leaders play in the budgeting process? (**Role of managers**)
 6. What role does the RDI director play in project budgeting; in RDI budgeting? (**Role of managers**)
-

(Exercise 1: Continued)

7. Take a look at the organization chart you drew for your RDI. Describe to your colleagues the levels and types of budgeting in your RDI. (**Tool for R&D coordination**)
 8. What kinds of financial information are routinely distributed among heads of all departments; and among research leaders? (**Exchanges of administrative information**)
 9. What budgetary control points does the RDI use in reviewing R&D programmes and projects? (**Control points**)
 10. How often does your RDI engage in regular reviews of the financial status of R&D projects and programmes? Who is involved in those reviews? (**Programme reviews**)
 11. What is the role of your RDI Director in ministerial, and national planning-level reviews of RDI budgets? (**All levels of involvement**)
-

5.171 **Summary:** In most RDIs preparing the annual budget is a major management activity. While specific budgeting methods may vary among RDIs, most of them are designed to answer the same two questions:

1. **How are government resources allocated to the RDI?**
2. **How are the allocated resources distributed among R&D projects and programmes within the RDI?**

5.172 Most RDIs commence budgeting operations with a target figure from government which establishes the general size of the R&D programme. This figure may come from the Ministry of Finance, a sectoral ministry, or other agency.

Which comes first, the annual allocation from government, or estimates of R&D project costs, done by the RDI?

5.173 With that target figure, RDIs then commence developing specific R&D project and programme budgets. Ultimately they aggregate costs for comparison to the probable allocation from government.

5.174 Finally, the R&D programme described by the detailed budgets is balanced and coordinated within the RDI and submitted to

government for final review, approval and allocation.

5.175 This is an iterative process. Most often the government decides on its allocation to the RDI on the basis of a proposal from the RDI. In such cases, the RDI goes through the budgeting process at least twice before it ever commences expenditure. The first time is for the sake of proposing costs for R&D to government. The second time is after government has decided on its ceiling for the RDI. Then, the RDI must reallocate to its priority projects on the basis of the final figures from government.

5.176 Quite obviously, key actors in this process are the RDI director (whose representational activities with government can have great influence on the target figure from government) and technical people (whose knowledge of research methods and technologies generates detailed budgets). **But in the last analysis, the success of this whole operation depends on the coordination and cooperation shared by RDI managers at both levels. Budgeting, like other elements of planning, has to be a team activity if it is to have a desired effect on the productivity of the RDI.**

If the annual government budget submission is based on R&D project cost estimates, why must projects be re-budgeted after the government has made their appropriation for the RDI?

5.181(a) **Seven Approaches to Budgeting R&D:** Visits to RDIs demonstrated seven basic approaches to deciding how money should be allocated among units in the RDI, and how budgets should be formulated. They are interesting to compare to each other. We gave them these names:

Allocation Methods

- Patriarchal decree
- Squeaky-wheel-gets-the-grease
- Share-the-loot
- Formula funding

Formulation Methods

- Planning, programming and budgeting
- Zero-based budgeting
- Hybrid

We made some of these names up to match the characteristics of the budgeting processes they represent. You will have trouble finding some of them in a management text.

5.181(b) Each has its merits and demerits—as was obviously recognized by those who use one of the “hybrid” techniques. Furthermore, few RDIs used any of these methods in their purest forms. Most RDIs adapted versions of these approaches to their budgeting needs.

5.182(a) **Patriarchal Decree:** This approach was most often found in RDIs in which top management exerts maximum control and authority over most major decision areas in the institute. It is a top-down strategy in which top management has complete control of the direction of research efforts and utilization of all resources—including money. It provides the greatest amount of consistent control over all resources in the RDI. It is found in RDIs which need not remain sharply tuned to fluctuations in the market place because they are assured of annual allocations from government.

What is the “Patriarchal Decree” approach to resource allocation?

Does it operate in your RDI?

5.182(b) Its greatest drawback is that it fosters insensitivity to changes in the needs of RDI constituents for new technologies; and it inhibits entrepreneurial development and responsiveness among RDI researchers. It leads to the generally relaxed (sometimes lazy) atmosphere which is characteristic of many government RDIs—largely because top management takes all responsibility for financial allocation and control. Lower level managers, and researchers feel no responsibility for financial performance.

What are its merits; and demerits?

How do R&D project people feel about the “Patriarchal Decree” approach?

5.183(a) **Squeaky-Wheel-Gets-the-Grease:** If you were driving a lorry and one wheel squeaked badly, where would you put a ration of lubricant? Budgeting works the same way in some RDIs. The R&D unit head who works the hardest, and offers the most untiring effort, gets the largest allocation. The allocation may, or may not, be based on the merits of the proposed R&D or the technology needs of end-users.

Describe the “Squeaky Wheel” approach to resource allocation.

5.183(b) To be successful, this approach obviously requires an element of patriarchal decree, combined with the persuasive qualities of personalities and relationships between managers. This approach can have the benefit of forming strong bonds between top management

Does it operate in your RDI?

What are its merits; and demerits?

and unit heads who are successful in their bid for funds. It encourages aggressive and articulate group leaders. But its greatest weakness is that it divorces the budgeting process from the objectives of the RDI, and the merits of individual R&D programmes and projects.

How do R&D project people feel about this approach?

5.184(a) **Share-the-loot:** This is an interesting approach to resource allocation. Users of it somehow assume that since resources are so scarce, nobody will receive all they think they should get. Therefore, in order to avoid charges of favouritism in allocation, the decision is made to distribute the limited resources equally.

Describe the "Loot" approach to resource allocation.

To what extent does it operate in your RDI?

5.184(b) In other words, resources are distributed without regard to considerations of priority among needs. This can be a very damaging approach because it means that all programmes and projects get started, i.e., committed to completion. But the financial resources usually dry-up long before completion. It can be a demoralizing experience.

What are its merits; and demerits?

What does a manager have to do to get R&D resources in this method?

5.184(c) Politicians sometimes favour this approach because they feel it avoids political alienation of those interest groups which would not rate highly on the basis of priority needs. In effect the share-the-loot approach to resource allocation helps politicians avoid the tough decisions of development priorities.

5.185(a) **Formula Funding:** This approach bases resource allocation decisions on the results of some mathematical formulation which was designed to apply the same standards for decision-making to every unit in the RDI. It is a bid for equity in decision-making.

Describe the "Formula" approach to resource allocation.

5.185(b) It is most common in large RDIs where equity is difficult to provide via studied analysis, open deliberation and fair judgments. In universities, for example, the formula may include such factors as technical papers published, degrees produced and credits delivered. In government RDIs the formula may include the number of people in the organization, space supervised, technical papers published, or even revenues generated from non-governmental sources.

Does it operate in your RDI? Give an example.

How do researchers feel about it?

5.185(c) The greatest strength of this approach is efficiency in decision-making. Once the data for each component of the formula are derived, decisions are as forthcoming as a mathematical solution.

What are its merits and demerits?

5.185(d) On the other hand, its greatest weakness is the non-human approach to management. It removes people's judgments from the decision process. It discourages individual and group initiatives and places an artificial obstacle in the relationships among levels of management.

5.186(a) **Planning, Programming and Budgeting System:** PPBS is similar to Formula Funding in that it was designed to bring rationality, as well as equity, to the budgeting process. It is based on operations research technologies and it treats each unit of the RDI as a financial subsystem. Data from each subsystem are meticulously designed and collected; then aggregations and mathematical transformation lead to decision options for management.

Describe the "PPBS" approach to RDI resource budgeting.

Have you ever seen it applied? Explain how it worked.

5.186(b) The PPBS greatest asset is its comprehensiveness. More complete and objective data are needed for it than for any other approach. But therein lies its greatest weakness also. It generates an extremely large volume of bureaucratic busy-work which alienates researchers.

What are some of its greatest strengths and weaknesses?

5.187(a) **Zero-Based Budgeting:** The principal contribution of this strategy is that it forces RDI management to reconsider continuing projects on a par with new ones for each budgeting cycle. It was designed to block the tendency for some projects to automatically receive funding simply because they were granted funds the year before.

Describe the "ZBB" budgeting approach.

Where does the "zero" come from?

5.187(b) That is why it is called "zero-based"; it forces all proposed project plans back to zero and asks management to reconsider them on their technical and economic merits. ZBB also requires budgetary forecasts for three possibilities: the same allocation as last year; an increase; or a decrease. That is an advisable element for any approach to budgeting.

What are its merits and demerits?

5.187(c) Its greatest asset is forcing managers to reconsider continuing projects. But its greatest weakness is that ZBB is extremely trying for all people concerned—largely because it is so comprehensive. And for the manager who must ultimately rank all RDI activities, a lot of personal stress is involved. Some of that stress is shared with researchers whose project futures are always in jeopardy.

5.187(d) Some RDIs have found ZBB to be very useful once every four or five years. Others have found it helpful when a new director takes over. It provides a good, analytical, overview for the entire RDI staff. It helps reorient everyone to the goals of the RDI and the technology needs of the country. But on an annual basis, it is far too strenuous.

5.188 **Hybrid:** Most RDIs use some combination of these generic approaches. But whatever the approach, certain characteristics are desirable. Exercise 2 lists nine of them.

What is the “hybrid” approach?

Exercise 2: List of Vital Elements in Any R&D Budgetary Decision Package

[Instructor(s): Each of these nine elements should be considered in detail. It is important that each participant understand what is meant by each of them. Further, they should consider whether they want to include them in their own RDI’s planning processes. You may wish to project them on a screen and discuss them in plenary. Or you may wish to construct small discussion groups—each of which is assigned the task of developing a real-life application of one element.

Give the participants time to examine and consider each of them. Instruct them on the use of the boxes as a guide for their own deliberations. By the end of this unit no participant should have a check in the “Don’t understand” boxes.]

Read, consider and answer each of these elements. Place a check in the box which best represents your reaction to them. If you have any check marks in the first column, ask the instructor(s) to help you understand the elements.

(Exercise 2: Continued)

		Don't Under- stand	Don't Do It	We Do it Already	Want To Do It
1.	A statement of project or programme goals to be funded.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.	List of tasks required to achieve goals.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.	Description of the expected results, benefits and achievements of the work.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4.	The consequences of failure to fund the proposed project or programme.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5.	How the project or programme could be done if it were funded at less than requested value.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6.	How project or programme could be speeded if it were funded at more than requested value.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7.	What other R&D projects or programmes, inside or outside RDI, provide alternative routes to same technical objectives.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8.	Proposed budgets for future years of the project under the three conditions of regular, reduced, or increased allocations.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.	Measures of interim technical and financial performance, and definitions of financial control points.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

2. Constructing an R&D Budget

5.211 **Introduction:** In the previous section we introduced the concept of budgets—as tools for planning finances for R&D. They apply equally to financial planning at the national level, the RDI level, or the R&D programme and project level. They do have different characteristics and functions at all these levels. But the basic concepts are the same.

5.212 In this section, we are going to construct a budget. We will relate it to an R&D project simply because that is a discrete subject with which most readers of this manual will be familiar. However, we hasten to point out that the processes of constructing budgets which we detail for this fictitious project apply equally at the other levels of financial planning.

5.213 Secondly, we would discourage readers from becoming distracted or preoccupied by the particular technical character of the fictitious R&D project we are using as a vehicle for discussing the budgeting process. An Ultra High Frequency Radio Receiver project was chosen because it is probably equally foreign to most R&D managers. Quite obviously if we picked a technology which was familiar to some (like an agricultural project), but not to others, we would be putting some readers to an unnecessary disadvantage. So do not become concerned with the technical character of our example. Do try to learn about the budgeting processes which we apply to it—and which apply to any other kind of project, as well.

5.221(a) **Costs:** Did anyone notice anything missing from the list of “vital elements” in R&D budgetary decision-making, in the exercise on the previous page? What about project costs; these too comprise a vital element of a project budget. Without them the document would not be a budget, would it? The reason they are missing from the list is because no RDIs ignore costs when designing project budgets; but many ignore these other nine elements.

An R&D programme or project budget should consist, exclusively, of financial information!

_____ True _____ False

Why?

We wish to emphasize that a proposed project or programme budget without these other nine

elements, provides insufficient basis for RDI managers to select R&D priorities for financial support.

5.221(b) The RDI exists to produce new technologies which enhance the country's development potential. It is effective if it does so within realistic resource parameters. It is not, if it does not. Therefore, every decision made in the RDI must be tied to considerations of its impact on R&D productivity.

Why do we emphasize this?

Do you agree with it?

Why, or why not?

Discuss it with others!

5.221(c) Financial decisions made by the most sophisticated financial managers must not be made in a vacuum of knowledge about their relationship to the R&D programmes and projects to which they are tied. That is why we must have all nine "vital elements" in support of every R&D project and programme cost proposal.

5.222(a) Cost Estimators: Who should be responsible for estimating the costs of an R&D project? Picture an RDI which is large enough to support a sophisticated financial accounting staff in the office of the controller. Should they be responsible for estimating the costs of a proposed R&D project? Or, how about an RDI in which the director makes all the resource decisions? Should the director propose the budgets for all R&D projects—even in a highly centralized management structure?

Who should be responsible for estimating the costs of an R&D project? Why?

5.222(b) Or what about a very large RDI; with half a dozen technical divisions and as many administrative support divisions? Should project budgets be developed and proposed by the heads of the technical divisions; or their project directors?

Who estimates these costs in your RDI?

5.222(c) Who estimates costs in your RDI? Some of these people (accountants and financial control personnel) are experts in money, finance, accounting and budgeting. Others (like the RDI director, and second-level managers) are experts in organization and decision-making. **But the technical people—the technical division heads, project leaders, researchers, technicians and research assistants—are experts in the work that**

is required to produce new technologies for national development.

5.222(d) All of these specialists must be involved in the work of developing project cost proposals. But the effort starts with the technical people. As we discussed earlier on the subject of planning, their first task is to break the project down into discrete technical tasks. They accomplish this with their special knowledge of the required technologies and the R&D methods needed to develop them. This is not a job for financial experts, or management experts—but for technical experts.

5.222(e) In this early stage of costing a project, financial and management experts can support the work of the technical people. For example, financial people can help set up the cost categories which must be considered by the technicians. And senior managers can help supply the methods used by technicians to analyse and negotiate the costs among themselves.

5.222(f) But the greatest initial burden rests on the research staff. At this preliminary stage of budgeting it is everyone else's job to support the technicians. Even though the quality of RDI financial planning depends entirely on the quality of researchers' estimates at this early stage, it is work they may dislike, or even resent, since it interferes with their research time. The balance of the RDI staff can make their job easier by providing whatever consultative guidance they need.

5.231(a) **Task List:** In the planning chapter we discussed the "task list" as a first step in planning an R&D project. That is also where we start costing an R&D project. You can see why we must rely on technical specialists to get our budgeting operation started. (You may wish to review what we said about task lists, at this time.)

5.231(b) Let us assume we are going to develop a budget for the Ultra High Frequency Radio Receiver project we planned earlier in this workshop. Remember, the principal technical tasks associated with this project are:

The RDI's financial and accounting personnel are experts in estimating the costs of R&D activities!

_____ True _____ False

Why?

R&D technical people are too research-, and scientific-oriented to make good project cost estimators!

_____ True _____ False

Why?

What is an R&D project task list?

1. Literature Search and Study
2. Develop Performance Specifications
3. Design Electronics
4. Make Circuit Boards and Test
5. Design Mechanics
6. Develop Parts Lists
7. Make Engineering Model
8. Test Engineering Model
9. Design Necessary Changes
10. Draw Schematics

5.231(c) The criteria for determining these tasks for this project were:

1. They are technically discrete
2. They are temporally discrete
3. They are financially discrete
4. They yield discrete results

What do these mean? You may review them on pages 116–117.

5.231(d) These important criteria were explained during the discussion of planning. Of course, the third criterion interests us most during the costing part of budget preparation. It means that each of these tasks is sufficiently separate from the others that costs can be developed for it without confusion from the financial requirements of other tasks.

5.232(a) **Cost Categories:** For this exercise let us assume that we are budgeting this project for one year—corresponding to the financial period which is most common in RDIs—called, the “fiscal year.” The next problem in costing the UHF Radio Receiver project is calculating the costs of each task, for one year. Quite obviously, it is not easy to develop a reliable estimate by guessing what each task will cost. Somehow we must break the costs down even further. In fact it would help if we could develop some cost categories which were more-or-less common to all tasks—like labour, materials, and so on.

What is a fiscal year? What are the dates of the fiscal year for your RDI? Are they the same as those for the government?

5.232(b) Here are some of the most probable sources of costs for each task:

- Personnel
- Special R&D services
- Equipment
- Materials and supplies

What are standard R&D project cost categories which you use in your RDI?

- Travel
- Meetings and courses

5.232(c) You may be able to think of others. But the main point is that these are **direct costs**. Direct costs are those which are directly attributable to the particular task, or project for which they are budgeted. Later we will introduce the concept of indirect costs; but for now, let us only consider those costs which would not exist if the particular task, or project, we are costing did not exist.

What are direct costs? Give some examples from your own RDI.

5.233(a) **Personnel:** Personnel are the greatest contributors to R&D costs. Therefore, one of the first tasks is to figure out how many person-hours are required for each task. We can then multiply that figure by the hourly salary of these people to determine personnel costs. But there are some easier ways to do this.

5.233(b) First, let us make these estimates on the basis of the same time-frame which we developed in planning this UHF Radio Receiver project. Exercise 3 in the planning chapter shows that we estimated four months of elapsed time for completion of the first task: Literature Search and Study. Therefore, let us set up a matrix which will help us determine labour costs over time for this task. Figure 1 shows an example:

What cost category is the greatest single contributor to the direct costs of R&D projects?

Figure 1. Calculating Labour Costs for One Task, Over Time

Project: UHF Radio Receiver—Task 1				
Task	Month 1	Month 2	Month 3	Month 4
1. Literature Search & Study				

5.233(c) Now, is it easier to estimate labour costs for this project task? Let us try it. It will probably take one person 10 working days to search the published bibliographies, card files and computerized indices of pertinent literature; especially since they will probably have to travel between three or four libraries in the country. We will probably also have to pay for library staff time

What information is needed to derive the total personnel costs for one task in an R&D project?

to assist our searcher—let us estimate a total of three working days.

5.233(d) Then we will have some costs associated with acquiring the books, articles and other materials. Some may simply be borrowed at no cost to the project. Others may have to be copied at some cost per page. Still others may have to be borrowed on interlibrary loan from some overseas libraries; we would incur some costs there. Still others may have to be purchased outright for the project library.

*Think about a project in your RDI.
What do you need to know to estimate total personnel costs?*

5.233(e) Are these labour costs? No. But there are some labour costs associated with them. Let us make note of these costs so that we do not overlook them when we estimate the costs of materials and supplies for this task. But let us add about five working days for our searcher to make all these arrangements.

5.233(f) Now assume we have all the library materials necessary for Task 1. What is next? Someone has to read and analyse all the material—pulling out those portions which are relevant to our UHF Radio Receiver project. Who will do that? The person who found the materials in the first place?

5.233(g) Probably not. We will probably want the project's senior researcher, or PI ("Principal Investigator"), to do this critical reading because it requires someone steeped in the technology so that they can sift out the information which will be most helpful for the project—and discard the rest.

5.233(h) Well then; who searched for the literature? It could have been the PI. But usually such routine tasks can be accomplished by less sophisticated, hence less expensive, research assistants. Occasionally the PIs' advice and direction may be needed; but generally a more junior scientist can do this.

5.233(i) Let us assume the PI will study the literature found by the research assistant. And we will give the PI 20 working days to complete the task. Next we need the PI to write the results of the literature search in a report for the project team.

Let us provide 15 working days for that. Then we will add five days for the research assistant to help the PI write the paper by designing data tables, drawing schematics, and editing the PIs' text.

5.233(j) A clerk-typist needs to prepare the report for distribution. That will require another five working days. And finally, let us add five working days of the PIs' time supervising all the other personnel on this task. **Figure 2** gives a summary of the labour required for this task:

Figure 2. Labour Cost Summary

<i>Project: UHF Radio Receiver</i>		
<i>Task: Literature Search and Study</i>		
<i>Analysis of Labour Requirements</i>		
1. Search for titles	Research Assistant	10 days
2. Search consultation	Library Staff	3 days
3. Acquire titles	Research Assistant	5 days
4. Study titles	Principal Investigator	20 days
5. Write report	Principal Investigator	15 days
6. Assist with report	Research Assistant	5 days
7. Type and copy report	Clerk-Typist	5 days
8. Overall supervision	Principal Investigator	5 days
TOTAL Work Days Required		68

5.233(k) Now are we ready to calculate a cost figure for labour on this task? What more do we need to know to estimate the cost of labour? We have to have a monetary value for a work day. There are a couple ways to do this. We could use an average calculated by dividing last year's total labour costs, by the total number of work days spent by all staff. We would then multiply this average by 68 days in order to estimate the total cost of labour for this task. That is assuming that this year's staff alignment and salaries are about the same as last year.

5.233(l) But that would not be as accurate as using salary averages for three different classes of personnel—principal investigators, research assistants and clerk-typists—based on current rates. We would probably be justified in estimating the daily rate of librarians as equivalent to that of research assistants. Or, we could generate a special rate for them too.

5.233(m) For this hypothetical case, let us use a monetary standard of U.S. dollars (\$). Here is how the RDI pays its staff:

Principal Investigators	\$48.00 per hour
Research Assistants	\$24.00 per hour
Clerk-Typists	\$12.00 per hour
(Librarians	\$24.00 per hour)

5.233(n) Now we have to know how many hours are in a work day at this RDI. Assuming there are 7.5 hours in a work day, the daily rate for these people turns out to be:

Principal Investigators	= \$48.00/hr. x 7.5hrs./day = \$360.00/day
Research Assistants	= \$24.00/hr. x 7.5hrs./day = \$180.00/day
Clerk-Typists	= \$12.00/hr. x 7.5hrs./day = \$90.00/day
(Librarians	= \$180.00/day)

5.233(o) Now let us redesign the labour costs table we started earlier by inserting rows for each classification of personnel. I will insert the distribution of work days for each person across the entire four-month period. I would like you to figure out how much money will be needed to pay all labour costs for each month, and totally across the entire task. Exercise 3 presents the table.

Exercise 3: Estimating Labour Costs for One Task

[Instructor(s): You may wish to have teams of participants work on this exercise together. It is principally a mathematical task on which they can double check each other's accuracy. Of course, it is also amenable to individual effort. Thus you may adapt the exercise to your schedule and the motivation and abilities of the participants.

It is important that from this exercise they learn the relationship between estimates of level-of-effort (work days per person) and costs of labour. They should be able to explain how this approach would be adjusted to fit the realities of planning in their own RDIs. That would be a useful discussion to summarize this exercise—in plenary.]

(Exercise 3 is continued on the next page)

(Exercise 3: Continued)**Project: UHF Radio Receiver****Task: Literature Search and Study****Personnel Cost Estimates**

Personnel	Month 1	Month 2	Month 3	Month 4
Principal Investigator		10	20	10
Research Assistant	10	5	5	
Clerk-Typist			2	3
Librarians	2	1		
TOTALS	12	16	27	13

1. The numbers in the spaces represent the number of work days we expect these people to spend each month of the task.
2. It might be wise to first sum the row totals to see if we have properly allocated the total number of work days per person. Compare the totals to the figures on **Figure 2**.
3. Then use the daily rates calculated on the last page to estimate the labour costs, per person, per month.
4. Then sum the labour costs to derive monthly totals (across all personnel) and person totals (across all four months).
5. Finally, write on the space below, the total personnel costs for this task:

TOTAL PERSONNEL COSTS = _____

DO NOT LOOK AT THE TABLE BELOW until you are ready to see our answers.

Personnel Cost Estimates

Personnel	Month 1	Month 2	Month 3	Month 4
Principal Investigator		10 = \$36*	20 = \$72	10 = \$36
Research Assistant	10 = \$18	5 = \$9	5 = \$9	
Clerk-Typist			2 = \$1.8	3 = \$2.7
Librarians	2 = \$3.6	1 = \$1.8		
TOTALS	12 = \$21.6	16 = \$46.8	27 = \$82.8	13 = \$38.7

* x \$ 100

TOTAL PERSONNEL COSTS = \$18,990U.S.

5.234 Salary Increases: When costing a project for next year's budget, it is important to not overlook any salary increases that may come about as a function of merit raises, or cost-of-living raises. Factor them right in the formula for calculating personnel costs. It is possible that salary increases anticipated in a budget like this do not come about. That is all right. The budget is not a guarantee that they will. Further, it is better to have a little excess in the budget, rather than not enough money to pay staff.

For what reasons are salary increases granted in your RDI?

5.235(a) Fringe Benefits: The same is true of what have become known as "**fringe benefits.**" These are perquisites which have monetary value; that is, they will cost the RDI some of its financial resources. Further, the value of them is usually tied by some ratio to the value of salaries. They may be housing or transportation allowances; health and/or life insurance; retirement pension programmes; or any of a number of other "benefits" of working for the RDI. The point is that their value must also be built-into the personnel cost estimates. This is usually done with the simple addition of some proportion of the base salary.

What are fringe benefits? List some from your own RDI.

5.235(b) It cannot be overstressed that **the whole point of planning and budgeting (or organizing, staffing, directing, controlling and evaluating, for that matter) is to increase R&D productivity to enhance national development. And unless the RDI has limitless financial resources, this must be done as cheaply and efficiently as possible.**

What is the relationship between planning, budgeting and R&D productivity?

5.235(c) Therefore, it is vital that all factors which contribute to personnel costs for the RDI be built-into the project budget.

5.236(a) Special Services: Many RDIs are organized functionally; i.e., divisions are defined by the technical specialty they practice. Frequently, however, particular R&D projects require the combined specialties of a number of divisions. For example our UHF Radio Receiver project may require some time in the Drafting Service where schematic drawings are made; then it goes to Electrical Engineering for production of circuit boards; then it goes to the Fabrication Shop for design of the chassis; then it goes to the Microwave Laboratory for testing; and all the test data goes to the Computing Centre for data analysis; and so on.

What "special service" cost categories operate in your RDI?

5.236(b) Other RDIs may contract some of these technical services with groups outside the RDI. For budgeting purposes, the question is, how do we plan expenditures for services which are direct costs to the project, fairly discrete, but not under the direct control and management of the R&D project team?

5.236(c) Estimates for the costs of special services are obtained by multiplying the time required for that service, by a service fee. The fee may be derived either from the actual salary of an identified specialist who will provide the service (adjusted for anticipated raises and fringe benefits) or the average labour rate computed for all specialists in the service unit (adjusted for anticipated raises and fringe benefits).

5.237(a) **Service Costs:** It would help if the RDI developed a standard for service costs. This would be a good job for the financial people in the RDI because it is largely an accounting task. It is an example of how these financial and accounting experts can support the planning efforts of technical people.

Describe a methodology by which RDI financial people could develop cost standards for special services.

5.237(b) Their purpose should be to derive a cost per unit for all special services of the RDI. Let us take a look at some examples. Assume that the RDI doing the UHF Radio Receiver project has the following research services available to all projects:

(Instructor: This is an opportunity to have another group exercise. Divide the participants into teams. After teamwork, have some of them report in plenary.)

- Mass Spectrometer
- Accelerator Centre
- Electromagnetic Transmissions Laboratory
- Computing Centre
- Pdinga Narrows Radio Telescope Station

5.237(c) This is a diverse mix of "services." One of them is a fairly small piece of specialized equipment which requires one specially trained operator. It should be fairly easy to develop cost standards for the mass spectrometer.

5.237(d) But, the Accelerator Centre is a whole cluster of buildings which house a very large electronic device; it requires a whole team of

specially trained operators. The ET Lab conducts a wide variety of functions, using diverse equipment, and skilled as well as unskilled workers.

5.237(e) The Computing Centre is certainly specialized. But within that specialty it has a variety of services to offer—each of which can be costed separately from the others. And finally there is a whole research station which includes staff, equipment, buildings, housing and food services, transport and real property.

5.237(f) The task for the RDI's accountants is to complete cost studies which will yield a cost per unit of service. Such a standard can then be provided to R&D project leaders to use in costing their work. **Again, the objective is to tie the costs of these service units to R&D productivity—the *raison d'être* of the whole RDI.**

5.237(g) A couple techniques are available to the accountants. One is to analyse the principal cost contributors of each service and sum them into a composite cost per unit of service. The principal difficulty with this technique is deriving a common denominator for each cost contributor so that they may be summed.

Describe a methodology which financial analysts could use to develop a cost standard for the Pdinga Narrows Radio Telescope Station.

5.237(h) For example, how do you add the cost of fuel for running a machine to the salary of a consulting engineer? Usually this problem is resolved by reducing each cost component to a unit of time. That is, we add the cost of running the machine for one hour, to the hourly salary for the engineer. We then charge for the service by the hour.

5.237(i) But another approach is to simply divide the total costs for the service centre last year, by the total number of hours (or days) it was used. This will generate an average cost per unit of time with which R&D project directors can cost their needs for the service.

5.237(j) The table on the next page shows some examples for the special services available in the RDI which is developing the UHF Radio Receiver.

5.237(k) With a list of standard service costs like this, most R&D technical directors should be able to estimate the costs of special services for their projects. Notice in this list, how the basis for unit costs shifts from service to service. In particular notice the costs for use of the Computing Centre. They are broken into smaller units of service since the range of needs for the Centre is so diverse and an overall average would probably be unfair to Centre users. This kind of a breakdown allows users to estimate the real costs for their specific needs:

Who should develop the unit costs used by R&D managers in estimating project costs?

Special Service	Unit Cost
- Mass spectrometer	\$200/hr.
- Accelerator centre	500/hr.
- Electromagnetic Transmissions Laboratory	160/hr.
- Computing Centre	
Processor Time	80/hr.
Input/Output Time	30/hr.
Card Reading	1.60/1000 cards
Card Punching	12/1000 cards
Lines Printed	2.80/1000 lines
Plotter Time	56/hr.
Keypunch and Verify	32/hr.
Programme Consulting	72/hr.
- Pdinga Narrows Radio Telescope Station	360/day

5.237(l) In contrast, the cost per unit for the Pdinga Narrows Radio Telescope Station is simply a daily average. This calculation is based on the assumptions that:

1. There are relatively few services available at the Station;
2. They are fairly standard for all users;
3. Regardless of service, the costs for running the Station are relatively stable.

5.237(m) Therefore, one standard cost per unit of service is offered R&D project leaders.

5.24 **Role of RDI Accountants:** It cannot be overemphasized that the cost studies leading up to a list of cost standards for special services are most appropriate for the RDI's financial specialists and accountants. This is in contrast to project budget-

ing—which, at least initially, is only appropriate for technical personnel. But see how the accountants can support the role of the technical people in planning? Financial planning has to be a team effort throughout the RDI.

What is the role of RDI administrators, accountants, and financial people, in R&D project, or programme, budgeting?

5.251(a) Budgeting Special Services: As with personnel costs, costs for special services can, and should, be planned over time. Let us assume, for example that the second task for the UHF Radio Receiver project (Develop Performance Specifications) requires some of the special services listed above. A review of the task list for this project, back in the Planning chapter, shows that the task is scheduled for a four-month period, starting in the second month of the project.

5.251(b) Using these cost standards, take a moment to estimate the cost of special services for the UHF Radio Receiver project, Task 2. **Exercise 4** provides instructions.

Exercise 4: Estimating Special Services Costs for One Task

[Instructor(s): This exercise may be treated in the same manner as Exercise 3. You may wish to have teams of participants work on it together; or you may desire individual effort. You might even consider an overnight “homework” assignment. As before, we recommend you encourage plenary discussions about how planning the costs for special research services applies to the participants’ own RDIs.]

Project: UHF Radio Receiver

Task: Develop Performance Specifications

Cost Estimates for Special Services

Special Service	Month 2	Month 3	Month 4	Month 5
ET Laboratory	10.00	15.00		
Pdinga Narrows Station		2.00	3.00	
Computing Centre				
Processor Time			0.75	
Input/Output			0.75	0.75
Lines Printed (x1000)				3.00
Plotter				0.50
Programme Consultant			0.50	0.50

TOTAL Costs Per Month

(Exercise 4 is continued on the next page)

(Exercise 4: Continued)

- 1. Your task is to insert the costs for these services in each cell.
- 2. Use the cost standards developed earlier.
- 3. The numbers we have inserted represent the amount of each service required, as determined by the technical people on the project. They are represented in the same units as the cost standards.
- 4. Sum the TOTAL Special Service costs per month. Follow that by deriving a TOTAL Special Service cost for the entire task.

TOTAL SPECIAL SERVICES COSTS = _____

DO NOT LOOK AT THE TABLE BELOW, until you are ready for our answers.

Project: UHF Radio Receiver
Task: Develop Performance Specifications

Cost Estimates for Special Services

Special Service	Month 2	Month 3	Month 4	Month 5
ET Laboratory	10.00=\$16*	15.00=24		
Pdinga Narrows Station		2.00=7.2	3.00=10.80	
Computing Centre				
Processor Time			0.75=6.00	
Input/Output			0.75=2.25	0.75=2.25
Lines Printed (x1000)				3.00=0.084
Plotter				0.50=0.28
Programme Consultant			0.50=0.36	0.50=0.36
TOTAL Costs Per Month	\$16.00	\$31.20	\$19.41	\$2.974

* x \$100

TOTAL SPECIAL SERVICES COSTS = \$6,958.40U.S.

5.252(a) **Equipment:** Often an R&D project requires specialized equipment; and by nature of being specialized, it is often expensive. It is fairly easy to budget a project for special equipment needs. The items should be identified and listed as an expense for the months in which the purchase of them is anticipated.

5.252(b) Let us assume, for example, that manufacturing and testing the engineering model

What capital equipment expenditures were most recently authorized in your RDI?

What is the monetary threshold above which the purchase of equipment becomes a matter for special approvals by management in your RDI?

of the UHF Radio Receiver (Tasks 7 and 8) will require the purchase of three pieces of equipment:

- Precision Oscilloscope Calibrator
- Capacitance Meter
- Microcomputer

5.252(c) Review of the project tasks, back in the Planning chapter, shows that these tasks occur in the fifth–eighth months of the project. So we simply plan the expenditure in the right months. Figure 3, below shows how we add these costs to our process of budgeting the project.

Figure 3. Budgeting Equipment Costs

<i>Project: UHF Radio Receiver</i>				
<i>Tasks: Make and Test Engineering Model</i>				
<i>Cost Estimates for Special Equipment</i>				
Special Equipment	Month 5	Month 6	Month 7	Month 8
Precision Oscilloscope Calibrator	\$600			
Capacitance Meter		640		
Microcomputer				8,800
TOTAL Costs per Month	\$600	\$640		\$8,800
TOTAL EQUIPMENT COSTS = \$10,040 U.S.				

5.253(a) **Capital Budget:** There is only one wrinkle in integrating plans for the purchase of expensive equipment with plans for all the other project expenditures. Generally the purchase of such equipment requires the outlay of large sums of cash—this is called a “capital outlay.” Many times RDI financial managers will want to make special arrangements with the equipment sellers, and bankers for these purchases. For example they may want to spread their payments over a longer period of time; they may want to borrow some money; or they may want to spread the costs of the equipment over a number of years.

5.253(b) Regardless, it will help if the expenses for capital equipment are shown and subtotaled in separate rows of the project budget so that RDI

Case 1: BUREAUCRATIC DELAYS IN PURCHASING SUPPLIES AND EQUIPMENT

An industrial RDI developed a good programme which included approximately 10% of its operating costs derived from contracted projects in the private sector.

The RDI was functionally organized with well differentiated roles and responsibilities for all units and divisions.

However, their policy for the purchase of supplies and equipment caused

accountants and financial officers may make whatever arrangements they desire to obtain the equipment when it is needed.

5.254(a) Maintenance, Materials and Supplies:

These commodities may be treated the same way as capital equipment for project budgeting purposes. The actual costs for each of them may be planned for the months in which they are expected to be purchased.

5.254(b) However, there are a couple things to remember. First, the purchase of capital equipment should be accompanied with studied consideration of maintenance and replacement parts and supplies to keep the new hardware functioning smoothly and efficiently. Nothing is worse than owning a piece of new, but broken, equipment. This is particularly important if the equipment, know-how and replacement parts have to come from far away—or are otherwise difficult to obtain. Budget for maintenance parts and supplies.

5.254(c) Secondly, routine supplies, like office paper, pencils, typewriter ribbons, and so on, need not be budgeted like capital equipment. An alternative is to budget a standard monthly amount for these kinds of supplies. Only develop a ratio which represents the relationship between the value of supplies needed and the amount of activity in the project.

5.254(d) This is another good job for the RDI accountants. Through careful examination of supplies consumption patterns they can develop a standard value for supplies needed to support one professional person-week. Then simply adding the number of professional person-weeks on the project will provide a key to how much money is needed for routine office supplies.

5.255(a) Travel: Travel can be a very large budget item. Everyone is familiar with the high costs of travel. Therefore it is important to plan for all the trips that will be required, even if some of them are not certain. At least money left over from cancelled trips can be used elsewhere. Whereas, a vital trip which cannot be paid for may threaten the life of the project.

long delays and set-backs in their technical productivity.

Any researcher who needed any commodity which was not in stock, had to requisition the item on a form that needed 7 signatures of approval. The signatures came from 6 different divisions. One division had to sign it twice!

Case 2: PATRIARCHAL PURCHASING POLICY BURDENS DIRECTOR AND DEMORALIZES RESEARCHERS

An agricultural RDI operated with funds provided by an association of private growers. That being the case, they were well funded. But the growers' association kept tight rein on the Director's use of research and development funds.

Therefore, the Director instituted a purchasing policy which removed any responsibility, for the decision to buy any item, from all researchers and administrators, with the exception of the Director, himself.

This RDI is very large, by any standards. They operate many laboratories and have thousands of hectares under cultivation. That notwithstanding, the Director personally decides whether to buy all commodities required by the RDI.

Needless to say, he spends an inordinate amount of time examining requisitions—many of which are for insignificant expenses.

Further, his researchers are reluctant to request the kinds of commodities which would enhance their productivity because they do not want to alienate their Director!

5.255(b) Travel costs usually breakdown into two major components:

- Transportation
- Food and lodging

5.255(c) Again, this is a case in which actual costs may be used. Or accountants may be able to provide standard units of cost.

5.255(d) Generally, if the trip is one-of-a-kind actual costs are used. But if the trips are frequent, then a standard unit cost may be used.

5.255(e) Transportation costs should include money for both air and ground transportation. Actual costs may be obtained from travel companies. Some estimates may have to be made for ground transportation, like taxis, since these figures vary so widely from city to city.

5.255(f) Food and lodging should also be estimated. Needless to say, it will be important for these estimates to be as accurate as possible. That means anticipating market fluctuations in travel costs. If the trip is many months away, it may be a good idea to inflate the anticipated expenditure by some percentage in order to anticipate normal fare and fee increases.

5.256 **Meetings and Courses:** Costs for meetings and courses should be anticipated and included in the project budget. Include those that have already been planned and obtain approvals to budget for special meetings which are anticipated but remain unscheduled. Most meetings and courses will require increases in the travel budget as well. It will be important to plan for meetings and courses even if the specific events and times have not been identified.

5.261 **Project Costs:** By the time R&D project leaders have completed this much budgeting on their respective projects, the foundation has been laid for all the budgeting activities of the RDI. For the most part, all that remains are various levels of aggregation of data generated at the project level.

As a result, the Director is overworked; researchers are frustrated; and purchases take a very long time—delaying R&D project productivity.

How do you budget for travel in your RDI? Is there a travel allowance for each project? Are travel costs included in the project budget?

Are training and meeting costs allocated to project budgets in your RDI?

What does "aggregation" mean?

5.262 Let us review. We have been talking about anticipating the annual expenditures for direct costs attributable to R&D projects. Further, we have analysed them by:

How does it apply to the RDI budgeting process?

- Cost component
- Project task
- Month of the project

5.262 We can array these figures in a variety of useful ways, as in Figure 4:

Figure 4. Variety of Ways to Array Project Budget Data

Project: UHF Radio Receiver									
Tasks	Personnel		Special Services	Equipment	Material Supplies	Travel	Meetings Courses		
Literature Search/Study	\$18.99*				8.00	0.80			
Dev. Performance Specs	20.00		69.584		1.00	0.80			
Design Electronics	32.00		55.00		4.00				
Mk/Tst Circuit Bds.	41.70		87.00		16.00				
Design Mechanics	37.90		36.00		3.50	2.10	0.20		
Dev. Parts List	5.00								
Mk Engineering Model	18.00		49.00	12.40	23.00				
Tst Engineering Model	21.00		32.00	88.00	4.70	0.80			
Design Necess. Changes	29.80								
Draw Schematics	33.60				2.10				
TOTALS	\$257.99		328.584	100.40	62.30	4.50	0.20		
* x \$100									
TOTAL PROJECT COSTS = \$75,397.40U.S.									
Tasks	M	J	J	A	S	O	N	D	J
Literature Search/Study	7.50*	3.29	10.00	7.00					
Dev. Performance Specs		14.50	23.50	42.20	11.184				
Design Electronics		17.00	23.00	7.50	11.00	28.00	4.50		
Mk/Tst Circuit Bds.				20.00	50.00	60.00	14.70		
Design Mechanics		6.00	14.00	12.00	11.70	17.00	16.00	3.00	
Dev. Parts List				2.00	3.00				
Mk Engineering Model					30.40	57.00	15.0		
Tst Engineering Model						48.84	73.26	24.40	
Design Necess. Changes						2.35	7.51	11.70	8.24
Draw Schematics			2.00	4.70	2.00	2.00	2.00	10.00	13.00
TOTALS	7.50	40.79	72.50	95.40	119.284	215.19	132.97	49.10	21.24
*x \$100									
TOTAL PROJECT COSTS = \$75,397.40									

5.263 We prefer the two arrays which appear in **Figure 4** because they gear both time and money to technical performance—the tasks comprising the R&D project. For the project manager's needs either of them is satisfactory. In fact, both would be helpful in monitoring and controlling progress on the project.

Have you ever seen budgets like these—in your RDI?

5.264 However, a third version would be of more help to RDI division heads and financial managers. The information used to generate the third budget format would come from project technical staff. It would be the same information as that used to draw up the two project budgets. But it would be arrayed differently.

By the way, underlined items in the first budget are the costs we developed together back on pages 194, 200–201

5.265 **Figure 5** presents a model for the kind of project budget which is most helpful to RDI financial control personnel. You will notice that it reflects no relationship between the expenditure of money and R&D technical progress. Nonetheless, it does help financial managers monitor and control the rate of expenditure in the RDI, and the costs of all resources which are applied to the projects.

5.266 Notice the “Miscellaneous” category of expenses. It is generally useful to have that for those costs which do not fit any of the prescribed categories.

5.267 Again, compare the budget format in **Figure 5** to those in **Figure 4**. Virtually the same types of information are offered in all three. But notice how the last format bears no relationship to R&D productivity. It is useful for telling us when various commodities should be purchased; and amounts of funds which should be expended. But, the acquisition of commodities and expenditure of funds does not necessarily equate to R&D productivity. That is why we prefer the former two formats for monitoring and control purposes at the level of the R&D project staff.

Which of the three budgets in Figures 4 and 5 relate costs most directly to technical performance on the project?

How can you tell?

5.271 **Division Budget:** As we have seen, project budgets are comprised of direct project expenses, i.e., expenditures for resources required by the project on a direct and accountable basis. Rarely are project budgets comprised of anything except direct expenses.

Which of the three relate costs most directly to time?

How can you tell?

Figure 5. Project Budget Relating Cost Components to Expense Periods

<i>Project: UHF Radio Receiver</i>										
Cost Component	M	J	J	A	S	O	N	D	J	TOTAL
Personnel (salary)										
B. Otali	\$xx	xx	xx	xx	xx	xx	xx	xx	xx	\$ xxx
U. Smithson	xx	xx	xx	—	—	—	—	—	—	xxx
D. Franolm	—	—	xx	xx	xx	xx	xx	—	—	xxx
G. Levy	—	xx	—	—	—	xx	xx	xx	xx	xxx
E. Shoku	xx	xx	xx	xx	xx	xx	—	—	—	xxx
T. Siila	xx	xx	xx	xx	xx	xx	xx	xx	xx	xxx
Subtotal Personnel	\$xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	\$xxxx
Fringe Benefits (_%)	xx	xx	xx	xx	xx	xx	xx	xx	xx	xxx
Special Services										
ET Laboratory	—	xx	xx	xx	xx	—	—	xx	—	xxx
Pdinga Station	—	—	xx	xx	—	—	—	—	—	xxx
Computing Centre	—	—	—	xx	xx	xx	—	—	—	xxx
Capital Equipment										
Calibrator	—	—	—	—	xx	—	—	—	—	xxx
Capacitance Meter	—	—	—	—	—	xx	—	—	—	xxx
Microcomputer	—	—	—	—	—	—	—	xx	—	xxx
Subtotal Capital Equip.	—	—	—	—	\$xx	\$xx	—	\$xx	—	\$xxxx
Materials & Supplies	xx	xx	xx	xx	xx	xx	xx	xx	xx	xxx
Travel										
Transportation	xx	xx	xx	xx	—	—	—	xx	xx	xxx
Food & Lodging	xx	xx	xx	xx	—	—	—	xx	xx	xxx
Meetings & Courses	—	—	—	—	xx	—	—	—	—	xxx
Miscellaneous	xx	xx	xx	xx	xx	xx	xx	xx	xx	xxx
TOTAL Costs for Period	\$xxx	\$xxx	\$xxx	\$xxx	\$xxx	\$xxx	\$xxx	\$xxx	\$xxx	\$xxxx

5.272 Most RDIs, however, also budget R&D expenses by organizational units. These budgets become the basis for managing a wider range of resources on behalf of a variety of R&D projects or programmes. Divisional budgets are the first step in aggregating project budgets to comprise the RDI budget.

Which format would you choose if you wanted the R&D budgeting process to stimulate technical performance as well as RDI economies?

Why?

5.273 The divisional budget is the sum of its period costs for projects, with the addition of some other costs. Divisional budgets include other sources of expenditure, called "indirect" and "overhead" expenses. These will be discussed in the next section, on special applications of R&D budgets.

3. *Application of Budgeting*

5.31 **Introduction:** We have talked, generally, about what budgets are and how they are used to make financial resource allocation decisions. Then we showed how budgets are developed, using the UHF Radio Receiver project as an example. Now it only remains to discuss some special concepts which you will encounter as you apply budgeting to your R&D planning practices.

5.321 **Continuing and Research Budgets:** This is a good place to point out where the budgeting approach we are promoting may differ significantly from the practice in many RDIs. We have visited many RDIs which operate under a government budgeting policy that separates personnel and other institute operating costs from the direct costs of R&D projects.

Does your RDI operate on the basis of continuing and research budgets? Explain.

5.322 Instead, such policies treat personnel and other operating costs as “Continuing” costs. They budget for them on an incremental basis—totally divorced from any consideration of R&D productivity of the personnel involved.

What happens to direct costs of R&D, like labour costs, in a dual-budget system like this? Explain.

5.323 In these situations, other direct costs for R&D, like supplies and materials, equipment and specialized facilities are budgeted in another plan called a “research” budget, or a “development” budget. If a project is not completed in one year, then in the second and subsequent years, its costs revert to the “continuing” budget, as part of the RDI’s continuing costs.

5.331 We might add that governments have a particularly difficult time denying requests for finances required by continuing budgets.

5.332 The net result is that RDIs become increasingly unable to manage financial resources on the basis of the real costs of R&D. They become increasingly unable to justify their financial requests on the basis of R&D productivity.

5.333 This is directly opposite to the approach we are taking in this workshop. Here we are emphasizing that the sole purpose of R&D management is to enhance R&D productivity for the sake of national development.

Why are we taking this approach?

5.334 As a consequence we are also assuming that RDI managers do want to account for RDI costs on the basis of R&D productivity. Hence it is necessary to monitor all R&D-related costs, including labour, and other operating expenses.

5.335 Therefore, we will continue to recommend integrating all financial planning in relation to R&D productivity. Admittedly, RDIs working under government financial policies of some other kind, will have difficulty adapting what we propose.

5.336 Further, they will probably have to continue providing the kinds of budgets government requires. However, internal planning and budgeting can be integrated. And we suggest that if it is, R&D productivity will increase; government will sit up and take note; and who knows, policies may even change. For these institutes, this means developing two budgeting strategies. We recommend adopting the integrated approach as a basis for management within the RDI; and as a basis for developing the budgets requested by government for external justification of the annual allocations.

5.341(a) **Indirect Expenses:** Indirect costs are those which are incurred by the RDI but which are not directly attributable to the requirements of projects. Indirect costs are considered controllable costs. Hence they are monitored and controlled—but not usually by R&D project technical staff.

What are indirect expenses?

List some of the sources of indirect expenses in your RDI:

5.341(b) Therefore, we do not recommend including indirect costs in project budgets. It is sufficient for them to be added during the first budget aggregation at the divisional level.

5.341(c) Indirect costs include, but are not limited to, such items as dues and subscriptions, library costs, maintenance expenses, general operating supplies, routine raw materials, routine travel, telephone expenses, and so on.

5.341(d) It is possible to forecast, in other words to budget, indirect costs. And it is very important for the RDI to monitor them and see that they do not grow out of proportion to direct

project expenses, or worse, R&D technical productivity.

5.341(e) The first indirect expense to be concerned about is "indirect salaries." These are salaries (plus increases and fringe benefits) for people who will not be charging their time directly to any particular project. They are vital to the life of the RDI and have to be paid whether or not the RDI is technically productive. They include people like the central administration and top management.

5.341(f) It is easy to see that the items which comprise indirect expenses are necessary for the work of the RDI, as a whole. Even more significantly, they are vital to support of the project activities. Where, after all, would the project technical people be without the RDI's technical library? Or general maintenance? Or routine supplies? Or top management?

How do planners in your RDI usually budget for what we are calling "indirect expense"?

5.341(g) Most RDIs budget indirect expenses as individual cost items (like direct expenses). Their total is compared to a general ratio standard which can be developed by the RDI's financial people. Usually it is some proportion of direct project personnel costs (in the vicinity of 100%).

Take a look at the organization chart back on page 69 and identify which people would have salaries in the indirect expense category.

5.341(h) Telephone costs can be a very large indirect expense item. There are two ways of budgeting for them. A history of telephone charges and RDI activity levels (like professional level-of-effort) can be used to develop a ratio which is multiplied by anticipated level-of-effort in the coming expense period. Or, they may simply be charged directly to a project.

What method could be used by your RDI accountants to develop a general indirect expense ratio standard which could be applied to most projects in the RDI?

5.341(i) The latter approach would only be preferred if the project were expected to contribute a significant amount of telephone charges to the RDI. They would then be treated as a direct expense of the project.

5.341(j) Remember, indirect expenses are incurred as a function of the work, R&D projects and programmes, of the RDI. This is in contrast to a group of expenses called "overhead". They are real costs; but they would exist even if the RDI did no work at all.

5.342(a) **Overhead Costs:** These are the cost of staying in business; the cost of running the RDI. They exist because the RDI exists. Frequently they are the costs encountered to own and operate the R&D facility — regardless of R&D productivity. They, too are indirect costs in that they cannot realistically be charged to any single project as a direct expense. However, without them, the RDI would be forced to close.

What are overhead costs? Why are they called "overhead"?

5.342(b) For example, they include such items as rent on property and buildings; depreciation; insurance; utilities; and allocated facilities costs. Certainly these expenses contribute significantly to the RDI's overall financial status. This has to be monitored and controlled by someone. But they play a less significant role on the disposition of individual projects. Therefore we recommend that they be budgeted, monitored and controlled, not by project personnel, but by the RDI's financial specialists.

How do planners in your RDI usually budget for what we are calling overhead cost?

5.342(c) Overhead is frequently budgeted as a lump sum. It is best controlled by controlling the items which compose it, rather than by allocating it to projects. Hence, the most common control practice is to budget each overhead item separately and to compare actual costs against the budget standard.

Who monitors and controls overhead costs in your RDI?

5.342(d) Building rent, utilities, insurance, and depreciation are fairly easy to budget since they are usually billed directly to the RDI and are therefore known by the financial people. They may, or may not, vary with activity levels in the RDI.

What is the researcher's role in managing overhead costs?

5.342(e) But there is also a simple technique for allocating R&D overhead to projects, on the basis of direct personnel hours, or costs. An overhead allocation rate is determined by dividing the overhead cost (for example, last year's overhead cost total) by the total labour hours or costs for the same period.

Take time to work through this exercise with us.

5.342(f) If labour hours is used, a combined labour and overhead rate per hour is often determined to allocate both these elements of cost to projects. **Figure 6**, on the next page, shows how this is done:

Follow each step and do not proceed until you understand it fully.

Figure 6. Simple Technique for Allocating R&D Overhead to Projects

1. Calculate the number of hours available per year, per employee.

$$52 \text{ weeks/year} @ 38.75 \text{ hours/week} = 2015 \text{ hours/year}$$
2. Subtract the paid hours during which employees are not working.

Holidays 12 days @ 7.75 hours/day	(93)
3-o'clock closings 5 @ 1.75 hours	(9)
Sicktime 10 days @ 7.75	(78)
Vacations 12 days @ 7.75	(93)
Miscellaneous report writing and meetings, etc.	(250)
TOTAL	(523)

Direct hours available/employee = $2015 - 523 = 1492 \text{ hours/yr.}$
3. Calculate the direct labour hours available to this RDI.

$$100 \text{ personnel} \times 1492 \text{ hours/employee/yr.} = 149200 \text{ hours/year}$$
4. Derive a direct labour rate.

$$\text{Total direct labour costs/total direct hours available} =$$

$$\$4,000,000 / 149200 \text{ hours} = \$26.81/\text{hour}$$
5. Derive an overhead rate.

$$\text{Total overhead costs/total direct hours available} =$$

$$\$6,604,900 / 149200 \text{ hours} = \$44.27/\text{hour}$$
6. Develop hourly personnel costs by combining these rates.

$$\text{Direct labour rate} + \text{overhead rate} =$$

$$\$26.81/\text{hour} + \$44.27/\text{hour} = \$71.08/\text{hour}$$

5.342(g) In other words, we could develop all our personnel costs, including overhead, by simply multiplying the number of personnel hours needed for each R&D task by the hourly combined rate of \$ 71.08U.S.

5.351(a) **Aggregating Project Budgets:**
 "Aggregating" means combining. Here, we are talking about combining all the budgets for separate projects conducted by a single unit of the RDI (called a "division"). Putting them all together in some fashion helps the division head know how much money to ask for each year.

5.351(b) Aggregating divisional budgets for the whole RDI, then, yields the RDI budget. Can you see how the RDI budget is built from the bottom-up by starting with individual project budgets; aggregating R&D programme budgets; aggregating RDI division budgets; and finally compiling the whole RDI budget?

5.351(c) But, let us not get ahead of ourselves. Here is how we develop divisional budgets from project budgets.

5.351(d) The divisional budget is derived by aggregating the budgets for R&D projects which fall within the span of control of the division; and, adding the division's indirect and overhead expenses. In a functionally organized RDI, like RDI #1 which is shown back in the chapter on Organization, this is a fairly straight forward process. Each department (or division) controls its own R&D projects and provides its own administrative assistance.

RDI #1 appears on page 69

5.351(e) Look, however, at RDI #2 on the same page. Here we see three R&D project divisions under a Deputy Director for Research and Development; and three administrative divisions under a Deputy Director for Administration. How is this aggregation achieved?

5.351(f) In this case the aggregation represents the total RDI budget, in which administrative costs (indirect costs and overhead) are added to the direct costs of projects. This represents the last aggregation for this RDI.

5.351(g) Figure 7, shows the aggregated divisional (or final costs for a small RDI) budget format.

Figure 7. Divisional (or Small RDI) Budget Format

Cost Component	Expense Period (Month)									
	M	J	J	A	S	O	N	D	J	Total
Project Costs (see indiv. project budgets)										
Personnel	\$ xx	xx	xx	xx	xx	xx	xx	xx	xx	\$xxx
Special Services	xx	xx	xx	xx	xx	xx	xx	xx	xx	xxx
Capital Equipment	xx	xx	xx	xx	xx	xx	xx	xx	xx	xxx
Materials & Supplies	xx	xx	xx	xx	xx	xx	xx	xx	xx	xxx
Travel	xx	xx	xx	xx	xx	xx	xx	xx	xx	xxx
Meetings & Courses	xx	xx	xx	xx	xx	xx	xx	xx	xx	xxx
Miscellaneous	xx	xx	xx	xx	xx	xx	xx	xx	xx	xxx
SUBTOTAL Project Costs	\$xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	\$xxxx
Indirect Costs										
Dues & Subscriptions	xx	xx	xx	xx	xx	xx	xx	xx	xx	xxx
Library	xx	xx	xx	xx	xx	xx	xx	xx	xx	xxx
Maintenance	xx	xx	xx	xx	xx	xx	xx	xx	xx	xxx
Routine Travel	xx	xx	xx	xx	xx	xx	xx	xx	xx	xxx
Telephone	xx	xx	xx	xx	xx	xx	xx	xx	xx	xxx
Accounting Office	xx	xx	xx	xx	xx	xx	xx	xx	xx	xxx
Purchasing Office	xx	xx	xx	xx	xx	xx	xx	xx	xx	xxx
Legal Office	xx	xx	xx	xx	xx	xx	xx	xx	xx	xxx
Personnel Office	xx	xx	xx	xx	xx	xx	xx	xx	xx	xxx
SUBTOTAL Indirect Costs	\$xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	\$xxxx
Overhead Costs										
Rents	xx	xx	xx	xx	xx	xx	xx	xx	xx	xxx
Utilities	xx	xx	xx	xx	xx	xx	xx	xx	xx	xxx
Equipment Depreciation	xx	xx	xx	xx	xx	xx	xx	xx	xx	xxx
Insurance	xx	xx	xx	xx	xx	xx	xx	xx	xx	xxx
SUBTOTAL Overhead Costs	\$xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	\$xxxx
Total Cost of Period	\$xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	\$xxxxx

5.352(a) **RDI Budget:** The final aggregation is accomplished when the divisions submit their budgets. Generally it is simply a matter of adding individual division budgets to generate RDI totals, in the same format as Figure 7, above.

Why aren't indirect costs included as part of project direct costs?

5.352(b) However, occasionally an RDI may wish to add overhead costs at this level. We do not recommend this because control of these costs is getting farther away from R&D productivity.

Why aren't overhead costs also included as part of project direct costs?

5.352(c) **Above and beyond all other considerations, it has to be remembered that all money and other resources are available solely for the purpose of producing R&D technologies for national development. Hence, their management should be geared, as closely as possible to R&D activities!**

Why do we emphasize this point right here? What is its significance for budgeting?

5.361 **Summary:** Planning financial expenditures is necessary to ensure the accomplishment of R&D technical objectives. Direct and indirect personnel costs are the major contributor to the costs of R&D. An RDI budget is developed by first, developing the cost estimates for individual R&D projects.

The purpose of budgeting monitoring and controlling finance in an RDI is not to reduce costs, to save money, or to encourage thrift in government.

5.362 In preparing the budget, personnel costs, are estimated first. They must include anticipated salary increases and fringe benefits. All other direct expenses are also arrayed. The budget is developed for a period of one fiscal year.

5.363 The most useful budget format for project level financial control relates expenses to technical productivity (project tasks). The most useful format for aggregated budgets (divisional or RDI) arrays a schedule of expenditures by cost component.

The purpose of budgeting, monitoring and controlling finances in an RDI is to spend money in that manner which has the greatest desirable impact on R&D technical productivity.

5.364 Financial planning (budgeting) is a management process which must be engaged by all managers, including technical project leadership. Further, the entire budgeting process is built on the foundation provided by the financial planning of non-financial personnel, viz., R&D project leadership.

(1) Why do we emphasize this point?

(2) What can we do in budgeting to encourage R&D productivity?

(3) Why do we insist that R&D technical people have the major role in RDI budgeting?

5.365 The role of the RDI's financial specialists early in the budgeting process is one of support and consultation to technical people who are required to estimate the costs of their anticipated R&D productivity. Financial people are the source of cost standards, cost histories, budgeting procedures, special analyses, budgeting formats, and any other financial technologies which would enhance the R&D project leaders' abilities to develop realistic and comprehensive project budgets.

(4) What is the role of RDI accountants and financial people in budgeting?

5.366 During divisional aggregations of project budgets, financial specialists become more directly involved in budgetary computations. They are frequently called upon to add the costs of indirect and overhead expenses.

5.367 Finally, the practices and procedures of R&D budgeting in RDIs will vary with government and RDI policies. However, all managers should strive to develop budgeting systems that monitor and control all finances in relationship to the demands for R&D productivity.

5.371(a) **The Budgeting Process:** The budgeting process should be set up on a cyclic basis starting well enough in advance of the turn of the fiscal year that all budgets can be developed, reviewed and approved. The design and initiation of the process may be the responsibility of senior management or financial personnel — working in consultation with technical people.

5.371(b) Any administrative process, like budgeting, must be developed in support of the demands for technical productivity of the unit. Too often administrative personnel (non-technical) forget that their responsibilities are to support the technical productivity of the RDI. Too often, administrative priorities take precedence over R&D ones.

5.371(c) In small RDIs the whole process may be easily implemented by the technical director teamed with the senior financial administrator. But in large RDIs it may be more productive to organize a committee to oversee the budgeting process. Their role should be advisory only—to the RDI Director. The committee should be comprised of R&D technical people as well as leadership from each major level of the organization. It should include appropriate financial experts as well.

5.371(d) At the project level, the committee provides formats and guidance to project leadership who are engaged in developing the Project budgets for the coming year. They also receive all project budgets and review them for comprehensiveness, accuracy and balance.

Case 3: SHARED PLANNING RESPONSIBILITY DEVELOPS MANAGEMENT SKILLS

An agricultural RDI has recently undergone a dramatic change of management. For over 15 years it has been managed by a Director who was skilled and comfortable at management decision-making.

But on his departure, a senior researcher was appointed Director. This person had functioned solely as a researcher in the RDI for 10 years. Perhaps his tenure with the RDI is what made the government think he was the best person to replace the old Director.

Regardless, he was given the position. But since his predecessor operated with an authoritarian style in a highly centralized organization, this researcher had absolutely no management experience.

It was the first annual budgeting exercise after his appointment when the new Director figured out how to reduce his burden. He assigned all his technical directors the task of developing preliminary project and programme budgets.

There was some immediate complaining on everybody's part. But the directors saw that he was not shirking his duty—he simply could not do it as well as they could.

So they did their budgets. He pooled them all together. And everybody picked up some vital management skills, responsibilities and pride.

5.372(a) **Budget Balance:** "Balanced budget" is a term which we hear often. Usually, it is used to refer to equivalence between income and costs. But, to a financial planner it means a whole lot more.

What is the budgeting process in your RDI?

5.372(b) Balance refers to some of the considerations which go into the first aggregation of project budgets, at the division level. When all project budgets are before them, the committee can assess such factors as:

What are the roles for the RDI Director, Deputy Director, Division Heads and Project Leaders?

- Ratio of support to technical personnel
- Schedule of disbursements and cash flow
- Need and impact of capital equipment
- Project compatibility or redundancy
- Distribution of indirect costs
- Need and guidelines for project budget revisions

How are divisional budgets coordinated and aggregated?

Who is responsible for ensuring equity in the planning of financial resources?

How is equity ensured?

5.372(c) Usually such a review leads to some recommended changes in project budgets before divisional budgets are developed. It is the committee's role to obtain approval for these changes from senior management, and assist R&D project leadership in integrating them in the project budgets.

5.381(a) **RDI Communication:** The project budget reviews provide an excellent, annual, opportunity for all RDI personnel—administrative and technical—to share with each other information about their own operations. It provides a forum for management to reaffirm the goals of the institute and the R&D objectives of the various projects. It serves as a reminder to all that while their particular functions and duties may vary, they are united in purpose.

5.381(b) In all RDIs it may be helpful to schedule brief, oral, project summaries by key technical staff. These summaries could include:

1. Description of each project
 - objectives
 - present status
 - products to date
 - anticipated products
 - specific R&D to be done

2. Project costs
 - to date
 - coming fiscal year
 - long-range forecasts
3. Project completion dates
4. Probabilities of success
 - technological
 - dissemination
 - implementation
5. Potential problem areas
 - technical
 - administrative

Explain the value of each of these elements to a Project Budget Review meeting.

6. Summary of budgetary considerations

5.381(c) This kind of information and review should accompany each project budget submission — regardless of whether the project is new or continuing. Consistent with the Zero-Based Budgeting philosophy, it forces all personnel to reconsider each project on its own merits and in the context of the RDI's very real resource opportunities and limitations.

5.381(d) Preparation for such a review can easily entail a month of activity before the review meeting. However, the required forethought and preparation is exactly what gives this budgeting process such value as a device for RDI planning.

5.382(a) **Recommendations to the Director:** From these reviews, RDI managers learn of potential and actual operating problems. From their review of budget information administrative managers become more familiar with the technical side of the institute. Such an exchange is critical to sound RDI planning.

Discuss with other participants some improvements in your RDI budgeting processes, which you would like to make when you get back.

What budgeting improvements do you think will be particularly difficult, or impossible to implement?

5.382(b) The budget committee recommends a final budget to the director of the RDI. If the committee has done its homework, there is rarely any need for significant changes in the RDI budget which they send to the director.

Why will they be so difficult?

5.382(c) Furthermore, the reviews usually generate a wide variety of other suggestions for

Discuss with others some ways of overcoming these difficulties.

improving management in all areas of the RDI . These are a valuable spinoff of the budget review process. It is important that the committee capture and forward them to the director, along with the budget documentation.

How can an RDI implement budgeting processes which may differ somewhat from the financial policies established by government?

5.383(a) **Budget Presentation:** At various times in the budgeting process, planners are called upon to present their budgets to a group of managers who must make various types of decisions. The point is that a budget presentation must be carefully designed.

Discuss some alternatives with the other participants.

5.383(b) Documents which reflect budgetary allocations must be designed to communicate clearly. Frequently this means that they should be fairly simple. In other words, the complex accounting sheets which are used to develop budgets are frequently too full of numbers to be effective for budgetary presentations.

5.383(c) Sometimes it helps to develop overhead projection slides, or flip charts, which depict the principal cost categories and summary aggregations. Remember, in any oral presentation visual aids are invaluable. But keep them simple.

5.383(d) Another recommendation is to make sure that anything depicted on paper, for a presentation, is also explained orally. In that way the documents serve to support discussion. They should not be expected to carry the entire burden of communication alone.

5.383(e) In preparing the oral presentation, planners should rehearse thoroughly. It sometimes helps for them to give their presentation to colleagues who helped develop the material. That way the colleagues can help look for flaws in the presentation.

5.383(f) Finally, the presenter must be prepared to answer questions. This is another place where colleagues can help. Let them ask questions during one rehearsal session—much as you expect the real audience to ask questions. This process will help sharpen the presentation.

5.384(a) **Budget Approval:** If the budget is adequately prepared, approval by the director is fairly routine. If not, the director may choose to send it back to committee for more work. Or, in the press of time, the director may be forced to centralize the process under “front office” supervision. But that is undesirable and will hopefully be unnecessary. The greatest benefits of planning and budgeting are to be derived from shared responsibilities throughout the institute.

5.384(b) Approval of the budget by the director usually entails two steps: submission of the RDI budget to higher levels of government; authorization to the operating units to proceed on the basis of the approved budget (subject only to talks with government).

5.385(a) **Requesting a Research Grant:** One National Council for Science and Technology (NCST) has developed a format for submitting requests for research money. We present it in the pages that remain. It is included as one example—not necessarily the only, or best example—of such a format. Each RDI, each national research planning group, each national government, probably has its own format. This one is included for educational purposes.

5.385(b) Of particular interest is the format for arraying budgetary information. Note that it is not the same format that is necessary for developing the budget. Rather, it is a simplified format which helps the decision-makers discern total costs for major categories of expenditure. Details of the budget are not requested in this presentation.

5.385(c) Also note that this form is, virtually, a research proposal format. In effect, R&D plans and budgets first come into play as R&D proposals. This is because resource allocation decisions are usually based on the proposal process. Hence, the R&D proposal is the first place in which plans and budgets appear—long before money is even available for R&D.

5.385(d) For that reason, we include in this manual, the next chapter on proposal writing. It is designed to show the role and relationship of

plans and budgets in the research proposal process.

5.385(e) The following NCST research proposal format can be used by the reader or a workshop instructor in any manner. Indications of the country of origin have been removed.

National Council for Science and Technology

FOR OFFICIAL USE ONLY

1. Received by NCST on:
2. File No.
3. Classification.....

FORM NCST 5A: APPLICATION FORM FOR A RESEARCH GRANT
(To be completed in Triplicate)

Note:
Applicants are advised to read both Part I and II of this form comprehensively before attempting to complete it.

PART I

1.	<div>Principal Investigator/Researcher</div> <div>Surname : Other Names : Nationality : Postal Address : Telephone Number :</div>
2.	<div>Institution where working</div> <div>Name : Postal Address : Telephone Number :</div>

3.		<p>Employment Status</p> <p>Present Post :</p> <p>State whether you are on probation, contract or permanent terms:</p> <p>If on contract terms, what date does your contract expire?</p> <p>Scientific field of specialization:</p> <p>Academic and professional qualifications:</p>								
4.		<p>Will there be any senior researchers working with you on this project? Yes/No.</p> <p>If yes, please list their names and addresses and attach their full curriculum vitae.</p> <table border="0"><thead><tr><th data-bbox="394 1284 474 1316">Name</th><th data-bbox="671 1284 777 1316">Address</th><th data-bbox="929 1284 1053 1321">Signature</th><th data-bbox="1150 1284 1214 1316">Date</th></tr></thead><tbody><tr><td colspan="4" style="height: 300px;"></td></tr></tbody></table>	Name	Address	Signature	Date				
Name	Address	Signature	Date							

5.		<p>Have you submitted other projects to the National Council for Science and Technology for funding?</p> <p>If yes, please state their title and reference number of the project and, where a decision has been made, please indicate the decision of the NCST.</p>
6.		<p>Title of the Present Project:</p>
7.	<p>1.</p> <p>2.</p>	<p>Duration of the Project:</p> <p>Expected commencement date of the project:</p>
	3.	<p>Is this research project expected to lead to an award for a higher degree?</p> <p>If yes, give details and attach official evidence from the University/Institution where you are registered.</p>

8.		Objective(s) of the project (list in summary form).
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9.		Project summary presentation: Brief comprehensive description of project including methods to be used:
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10.		State whether to the best of your knowledge similar work has been done elsewhere and results (if known to you) and what further contribution the project is expected to make.				
11.		Budget Summary of Assistance Requested from the NCST				
		ITEM	1ST YEAR	2ND YEAR	3RD YEAR	TOTAL
	1.	Personal Emoluments				
	2.	Major Equipment				
	3.	Expendable Supplies				
	4.	Travelling				
	5.	Subsistence				
	6.	Data Analyses				
	7.	Publications				
	8.	Other Expenditures				
		TOTAL				

12.	BUDGET DETAILS Note The budget should be fully justified in the proposal and it should be developed from the activities which will be carried out in connection with this project. Personal emoluments should exclude salaries of grantee or any other researchers who are already employed by or with the grantee. All the budget should be presented in _____ and should EXCLUDE expected supplementary sources other than NCST. For supplementary support from sources other than NCST, see items 12.11 (b) and 13.1 to 13.5.							
1.	Personal Emoluments (In)	Total Man Months	Salary per Month	Year 1 Costs	Year 2 Costs	Year 3 Costs	Total Costs	
	a. Research Assistants (specify category of Research Assistants) (a) (b) (c) (d) b. Casuals or Labourers							
	Sub-Total							

12.	2.	Major Equipments (List below)	Quantity	Cost per item	Year 1 Costs	Year 2 Costs	Year 3 Costs	Total Cost
		Sub-Total						
12.	3.	Expendable Supplies	Quantity	Cost per item	Year 1 Costs	Year 2 Costs	Year 3 Costs	Total Cost
		1. Chemicals (List below)						
		Sub-Total						

12.	3.	Expendable Supplies (contd)	Quantity	Cost per Item	Year 1 Costs	Year 2 Costs	Year 3 Costs	Total Cost
		2. Glassware (List below)						
		Sub-Total						
		3. Other expendable supplies (Specify and list below)						
		Sub-Total						

[illegible]

12.	6.	Data Analysis/ Computer Costs	Description	Year 1 Costs	Year 2 Costs	Year 3 Costs	Total Costs
		Sub-Total					

12.	7.	Publication	Description	Year 1 Costs	Year 2 Costs	Year 3 Costs	Total Costs
		Sub-Total					

12.	8.	Other Expenditures	Quantity	Cost per item	Year 1 Costs	Year 2 Costs	Year 3 Costs	Total Costs
		Sub-Total						
12.	9.	Grand Total						

12.	10.	Estimated Total cost of the Research project is
12.	11.	<p>(a) Total amount of assistance requested from NCST in (item 12.9)</p> <p>(b) Other costs to be provided from sources other than NCST details of which are given in items 13.1–13.5 below</p> <p style="text-align: right;">Total Cost of Research Project.</p>
13.	1.	<p>Support/collaboration from elsewhere</p> <p>Give particulars of available or/and expected support from your institution or any other institution e.g. Finance, equipments etc.</p>
13.	2.	<p>Is this project being sponsored by any other organization. If Yes, give details, including level of finances, equipments and other items to be provided by the sponsor.</p>

13.	3.	<p>Has this project been sponsored in the past by other institutions? Yes/No.</p> <p>If so give details:</p>
13.	4.	<p>Has the project been submitted to another organization for the purpose of soliciting funds?</p> <p>If Yes give details:</p>
13.	5.	<p>Indicate details of other form of collaboration from other persons or institutions which is not covered in part 13.1–13.4 above</p>

14.	1.	<p>Names and addresses of three competent referees in connection with this application:</p> <p>Name:</p> <p>Postal Address:</p> <p>Signature of Referee:</p> <p>Date:</p>
14.	2.	<p>Name:</p> <p>Postal Address:</p> <p>Signature of Referee:</p> <p>Date:</p>
14.	3.	<p>Name:</p> <p>Postal Address:</p> <p>Signature of Referee:</p> <p>Date:</p>

15.	<p>Declaration by the Principal Investigator/Researcher</p> <p>I declare that the information supplied above by me is to the best of my knowledge true and accurate and that I have read the notes in Part II of this application form:</p> <p>Signature :</p> <p>Name :</p> <p>Date :</p>	
16.	<p>Comments by immediate superior of the applicant on the applicant's ability to undertake research in respect of which NCST assistance is sought.</p> <p>Signature:</p> <p>Name :</p> <p>Institution and Address :</p>	

17.	1.	<p>Department coordinating or accommodating the project:</p> <p>Name of Department and Address:</p>
17.	2.	<p>Declaration by head of Department (Where applicable)</p> <p>I confirm that I have read this application and that:</p> <ul style="list-style-type: none"> (a) The equipments and facilities requested for in this application are necessary and not available in the department. (b) Terms of employment of the applicant are as indicated in Part I Section 3. (c) The application has got the support of the department and that if the applicant is allocated a grant, the research work will be accommodated in the Department. <p>Head of Department/Institution</p> <p>Signature :</p> <p>Name :</p> <p>Institution :</p> <p>Date :</p>

18.	1.	<p>Public Institution responsible for the administration of the funds for this project:</p> <p>Name:</p> <p>Declaration by the officer responsible for the administration of the NCST Grant.</p> <p>I confirm that if the grant is approved for this research project, it will be administered by the</p> <p>(Name of the Institution)</p> <p>Signature:</p> <p>Name:</p> <p>Title:</p> <p>Institution and address:</p> <p>Date:</p>
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PART II*Notes to be read before completing the application forms*

1. The forms should be completed in black ink and all accompanying papers should be in A4 size papers, i.e., the size of this application form.
2. The completed forms must be accompanied by *three* copies of a full project proposal which should include:
 - (a) Background and Literature review
 - (b) Objectives
 - (c) Theories behind the research project
 - (d) Methods to be used
 - (e) Envisaged use of the results
 - (f) Questionnaires to be used (if any)
 - (g) A full justification for the budget
3. Full Curriculum Vitae of all the applicants should be attached.
4. It is important to make sure that items are neither seriously undercosted nor overcosted.
5. No grant will be made for a project similar to work already being undertaken at any of the publicly supported establishments. Similarly, grants will not be made for equipment or facilities which are available in the institution where the applicant is working or where they can be made accessible to the applicant, unless there is a proven need for additional equipment and facilities.
6. An applicant who receives a grant will be required to undertake to submit full six monthly and final reports on the progress of work to which the grant relates.
7. Results of a research project supported by an NCST grant will not be published or disposed of in any manner without the prior consent of the Council. In addition, equipment and facilities funded by NCST Research Grants will remain property of the Council.
8. Project proposals should be submitted at least six months before the effective date of starting the project.
9. Expenditures incurred before the effective date of the grant may not be charged to the grant.
10. To avoid delays or possible rejection of the proposal, it is important to note that the application forms and the full project proposal should not be treated as substitutes: For example forms completed by simply saying "See attached proposal" or vice versa will not be accepted. Also forms which are not completed fully will not be accepted.
11. The application or any request for further information should be addressed to:

The Secretary,
National Council for Science and Technology

BUDGETING: Selected readings for more study

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- Beenhakker, Henri L. "Effect of Delays on the Present Value of a Project". **IEEE Transactions on Engineering Management**; August, 1974; EM-21 (3): 95-101.
- Bisio, Attilio and Gastwirt, L. E. "R&D Expenditures and Corporate Planning". **Research Management**; January, 1980: 23-26.
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- Ellis, L. W. "Optimum Research Spending Reexamined". **Research Management**; May, 1980: 22-24.
- Foster, Richard N. "Estimating Research Payoff by Internal Rate of Return Method". **Research Management**; November, 1971: 27-43.
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- Gambs, Gerard C., Assistant to the Vice President, Research and Development (Consolidated Coal Company). "Representative Costs of Doing Research and Development". In: **Industrial Research Institute—Young Presidents' Organization**. Symposium on Industrial Research; March 2-3, 1959: 33-43.
- Gibson, J. E. "Planning and Budgeting: Keys to Successful R&D". **Machine Design**; July 20, 1978: 58-63.
- Hanson, W. T., Jr. and Nason, H. K. "Funding and Budgeting R&D Equipment and Facilities". **Research Management**; September, 1980: 25-28.
- Harvey, Robert E. "Putting a Price Tag on Research". **Iron Age**; October 6, 1980: 71-75.
- Kipp, E. M. "How to Construct an Effective Corporate R&D Budget". **Research Management**; May, 1978: 14-17.

- Kornfeld, Jack P. "Cost-Effectiveness as a Method of Evaluating Design Changes". *IRE Transactions on Engineering Management*; March, 1962: 15-23.
- Lambert, Vernon L. and Sackett, Hubert F. "Research and Development Cost Estimation". *IRE Transactions on Engineering Management*; March, 1959: 8-12.
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*MANAGEMENT MANUAL FOR PRODUCTIVE R&D:
R&D STRATEGIC AND PROJECT PLANNING AND BUDGETING*

CHAPTER VI
PROPOSING

PROPOSING

Training Objectives

By the end of this chapter, participants will be able to:

1. Define the purpose and significance of an R&D project proposal.
 2. Explain the relationship of an R&D proposal to R&D planning and budgeting processes.
 3. Distinguish the roles and relationships among R&D project proposals, plans and reports.
 4. Explain the content and functions of 13 principal parts of an R&D project, or programme, proposal.
 5. Propose an effective proposal review process.
 6. Describe the uses, as well as strengths and weaknesses, of peer reviews for R&D proposal review purposes.
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PROPOSING

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All of this material could be covered in one session, if it has been studied on an individual basis prior to the session. However, the difficulty of some of the concepts may justify breaking it into two sessions.

CHAPTER VI

PROPOSING

Managing R&D is, in many ways, like managing in a fantasy world. We assume we know what we are trying to do, yet the results of our efforts remain unknown until we have finished. It is this fantasy quality to R&D which makes planning and budgeting so important. In lieu of known outcomes of R&D, we can manage R&D resource inputs, through the plans for expenditure of them. Our need to know is fulfilled through a surrogate—until the results of our projects and programmes are realized. The most useful surrogate in any R&D enterprise is the R&D project proposal. There, in one document, are collected all the known purposes, properties and potentials for the unknown results of R&D. The R&D proposal is the basis for all managers to decide whether, when and how to conduct R&D.

6.11 **Introduction:** We chose to add a unit on R&D proposal writing to a workshop on planning and budgeting because the R&D proposal represents the most comprehensive statement of both the desired ends of R&D, and the means for achieving them. The proposal is really the anchor for anyone involved in the project.

6.12 This chapter only highlights the role and methods of proposing R&D. It focuses, in particular, on the role of planning and budgeting in R&D proposals.

6.13 Anyone can go to the proposal to find out what is to be accomplished by the project; what are

Do project proposals in your RDI tell:

- (1) How expected results relate to national development needs?*
- (2) Why the project is the best alternative to fill this need?*
- (3) The scope and limitations of the project?*
- (4) The specific objectives of the project?*

the expected results. Anyone can turn to the proposal to find out how the expected results of R&D relate to national development needs. Anyone can go to the proposal to find out what resources are needed to achieve project results; or, what related technical work has already contributed to project completion. Anyone can read there, what technical steps are required to complete the project; and how they, and vital resources, are scheduled.

6.21 Definition: In short, the **project proposal** is a statement of justification for the objectives, methods, resources and management of an R&D project. It has many uses. At the project level it informs all project personnel about the purpose of their efforts. It serves to keep their hopes and expectations in line with those of other managers responsible for RDI resources.

6.22 At divisional levels, it helps convince managers to allocate resources to the project; and it gives them a basis for monitoring resource expenditure and technical progress.

6.23 At the top of the RDI it helps senior managers integrate all the institute's R&D into a programme which will have the greatest impact on national development needs. It keeps them informed on the technical elements of the RDI. It provides them a ready basis for explaining the RDI to constituents outside the institute.

6.24 Further, it is the first document in the life of any R&D project, which pulls together project purposes, plans and budgets (among other things). The project proposal provides the opportunity to integrate plans and budgets.

6.31 Proposal Writers: Who writes project proposals in your RDI? Accountants? Financial control personnel? Senior management? Divisional heads? Of course it depends on the nature of the proposal and its intended uses. But generally speaking, project proposals are best when written by the project technical people who will be responsible for carrying out the R&D.

(5) *Technical approach to the project?*

(6) *All resources needed for it?*

(7) *How the project will be managed?*

What are the purposes for an R&D proposal?

Who, in an RDI, will find it useful?

How will they use it?

Who writes R&D proposals in your RDI? Why are they the ones to write them?

Is there a role for accountants and other administrators in the writing of R&D project proposals? Explain.

6.32 As with project budgeting, they will need the help and consultative guidance of accountants, financial control personnel and senior management. But the principal effort is that of capturing, on paper, the purposes, processes and sequence of technical operations about which few others in the RDI may be qualified to comment.

6.411 **Proposals, Plans and Reports:** What are the differences and similarities of R&D project proposals, plans and reports? All three of them focus on the same thing, viz., the expenditure of identified resources, on specialized scientific processes, to achieve desired technical ends. But how do they differ? Let us start with definitions of each of them.

What are similarities and differences among the proposal, plan and final report for a single R&D project?

6.412 We defined proposals at the beginning of this chapter. An R&D **plan**, on the other hand, is a logical statement of the sequence of events leading to the accomplishment of specific technical objectives. It may be a stand-alone document, like a workplan. Or, it may be embodied in something else—like an R&D proposal.

6.413 A **report** could even contain a plan—depending on its purpose. It is a concise, written and/or oral, presentation of the planning, execution, management or results of an R&D project. Its basic intent is to inform a naive audience about some aspect of the project. Whereas, the purpose of a plan could be to further enlighten and direct the efforts of project workers themselves.

6.414 The principal differences between these documents relate to issues of purpose, timing and levels of detail. In the first place, the proposal is written even before the R&D project has been approved for the RDI work programme; even before resources have been allocated for it. In fact, one of the earliest goals of the project proposal is to convince RDI managers and financial sources that the project is worth consideration for resource expenditures.

Looking back at your own RDI:

- *Do all three of these exist for each project?*
- *Where is each of them, for any single project?*
- *Who wrote each of them?*
- *What are they used for?*

6.415 Secondly, the project proposal does incorporate information on the R&D process including tasks and methods, costs per task and

Who are the audiences for R&D proposals, plans and reports?

total resources needed. However, it does so in less detail than does the workplan. In fact, the proposal provides sufficient detail to justify a decision on whether or not to conduct the programme of research. But decisions about actual resource allocations and scheduling await completion of the R&D plan. The plan is developed after a project has received at least preliminary approval for inclusion in the RDI work programme.

Are they the same? Explain.

Do they require the same kind of information about the same project or programme? Explain.

6.416 Finally, the project report explains the real outcomes of R&D work. It relates what results from the effort, to what was hoped or expected (as based on the project proposal). Therefore, the report comes later than even the project plan.

6.417 A project report may come before the project is completed. For example, management may require quarterly reports of project progress. But it still focuses on outcomes, or results, of R&D work. And its principal point of comparison is the proposal, i.e., what was expected in the way of outcomes. **Figure 1** compares all three of these documents.

Figure 1. Comparison of R&D Project Proposal, Plan and Reports

Document	Purpose	Timing
Project Proposal	<ol style="list-style-type: none"> 1. Informs about expected results of the project. 2. Levers resources for the project. 	Before the project is approved or funded.
Project Plan	<ol style="list-style-type: none"> 1. Informs about R&D processes required by the project. 2. Schedules project resources. 	Immediately after the project is approved (at least tentatively).
Project Report	<ol style="list-style-type: none"> 1. Informs about real project results. 2. Basis for evaluating resource expenditures. 	Periodically during, and at the conclusion of, the project.

6.421 **Tie That Binds:** There is one element which binds all three of these documents together. It goes to the heart of this whole R&D management discussion.

6.422 All the R&D work of the RDI is designed to enhance national development—to somehow improve the status of life in a country. As we have said before, any management tool is simply servants of this greater goal. Proposals, budgets and plans are servants; supplies, equipment and even personnel are such servants. **Even managers, the director and the RDI itself are servants of a greater goal—R&D productivity for national development.**

6.423 One consequence is that all project proposals, plans and reports have in common a status report on the project's relationship to that overriding concern. The proposal tells how the project is expected to enhance national development needs; we call this portion of the proposal the "statement of project goals."

6.424 The project plan spells-out the R&D tasks for each goal and specifies just exactly what results will be achieved by each task. We call these the "technical objectives" of the project.

6.425 The report details just exactly what was achieved by the project, or some task of the project. In other words, it provides an indication of how well the project is achieving its purposes. We call these the "results" of the project.

6.426 Project goals, technical objectives, tasks and project results are the closest possible approximations of the results of research and development—R&D productivity. They are the tie that binds all three documents together. They are the tie that binds together the RDI and all its human and other resources.

6.51 **Proposal Content:** R&D project proposals can have different contents, formats, even purposes. A lot depends on the nature of the project, the technical people involved, and the needs and requirements of the RDI for a comprehensive proposal. That notwithstanding,

What are the differences and similarities among:

- project goals,
- technical objectives,
- project results?

Explain?

Why do we emphasize the statement in boldface type, above in paragraph 6.422?

Do R&D proposals in your RDI currently have all these parts?

we propose the following thirteen basic topics for inclusion in an R&D project proposal:

BLACKEN the right circle for each part!

	YES	NO
1. Statement of the Problem and Intended Uses of the Proposed Technology	<input type="radio"/>	<input type="radio"/>
2. Goals of R&D	<input type="radio"/>	<input type="radio"/>
3. Project Justification	<input type="radio"/>	<input type="radio"/>
4. Scope and Limitations of the Project	<input type="radio"/>	<input type="radio"/>
5. R&D Methodologies and Procedures	<input type="radio"/>	<input type="radio"/>
6. Role of Project Beneficiaries	<input type="radio"/>	<input type="radio"/>
7. Scheduling and Summary of Workplan	<input type="radio"/>	<input type="radio"/>
8. Facilities, Organization and Personnel	<input type="radio"/>	<input type="radio"/>
9. Budget	<input type="radio"/>	<input type="radio"/>
10. Expected Outcomes of the Project	<input type="radio"/>	<input type="radio"/>
11. Dissemination and Transfer to Beneficiaries	<input type="radio"/>	<input type="radio"/>
12. Other Pertinent Information	<input type="radio"/>	<input type="radio"/>
13. Summary	<input type="radio"/>	<input type="radio"/>

6.521 Statement of the Problem: Here is one of the first places where the R&D manager has the opportunity to cement the relationship between R&D and national development. Here, at the very beginning of the R&D project deliberation, are stated the national development problems and opportunities which will be addressed by the proposed project.

6.522 The purpose of this first section of the proposal is to explain those requirements for national development which will, at least in part, be fulfilled through completion of the proposed R&D. But it has to be remembered that whether or not this project gets funded, may depend, in large part, on how well this first portion of the proposal is written.

For each of the NO circles which you BLACKENED, above, answer the following questions.

- *Why isn't this part of your RDI's R&D proposals?*
- *Should this part become an element of your proposals?*
- *Why, or why not?*
- *How would the addition of this element enhance your RDI's R&D proposals?*

6.523 If the author can show a clear and imperative relationship between national development needs and project goals, then chances are good that priorities can be shifted in favour of the project. But if that relationship is not there, or at least poorly developed, then priorities may well shift to some other activities.

6.524 One good way to demonstrate the relationship between the proposed R&D and national development is to explain how the derived technologies will actually be used by the target beneficiaries. This also has the advantage of focusing all participants in the R&D process on utilization. It helps reduce the tendency in R&D circles to develop new knowledge and technologies which do not have an immediate application.

6.531 **Project Goals:** Many times, this first section of the proposal concludes with a statement of the R&D project goals. Goals are general statements of the desired outcomes of R&D. They make good conclusions of the earlier discussion of national development needs. Further, they make good introductory remarks for the next proposal section on R&D technical objectives.

6.532 Note, there must be an inherent logical consistency between any explanation of these three elements

- National Development Needs
- R&D Project Goals
- Project Technical Objectives

6.533 As an example let us return to our UHF Radio Receiver project. Assume for the sake of the example that it is proposed by an RDI in a country which has a population that is widely distributed in a geologically and meteorologically active area. Let us continue by examining part of the Statement of the Problem which accompanied the RDI's proposal for the UHF Radio Receiver project:

R&D productivity for national development starts here—with the original statement of the development problem which may, in part, be resolved through successful R&D.

What is the difference between the statement of a development problem, and a statement of an R&D project goal?

How do they relate to each other?

What would we have to add to this list of three elements, to make a complete and logical statement about the relationship between national development and R&D? (See the answer in the box below.)

Answer: Project results

Statement of R&D Problem:

... Torrential rains, flash floods, earthquakes and typhoons, with their attendant damages to people and property, are not uncommon throughout the region. The need therefore exists for the Government to provide an Early Warning System (EWS) so that all citizens may be warned of impending hazards, and may take preventive steps to protect themselves and their property....

One element of the EWS will be a radio instrument which is capable of receiving notifications of impending hazards, broadcast from the National Geologic and Weather Administration in the country's capital.

The UHF Radio Receiver must run for long durations on battery power, adaptable to solar or wind regeneration. It must be light weight (for portability) and must be able to withstand the onslaught of extreme weather conditions typical of subtropical regions.

6.534 Notice in this example how the discussion of the problem leads to specification of some of the vital characteristics of any proposed solution to that problem. That is the point of departure for a statement of R&D project goals. They might include the following:

Statement of R&D Project Goals:

... It is the intent of this project to develop the prototype and manufacturing specifications for a UHF Radio Receiver which has the following capabilities:

1. ... to operate on a Nickel-Cadmium power pack for an extended duration of 4 hours; or for an intermittent duration of 12 hours. ...
2. ... to weigh no more than 5 kilograms for easy portability. ...
3. ... to have an effective receiving range of 500 kilometres. ...

6.535 Can you see a logical connection between the Statement of the Problem and the Statement of Project Goals? Which goals are directly supported in the statement of need? Which ones are not? How could the Statement of the Problem be enhanced to strengthen the imperative for achievement of the project goals?

Answer these questions!

6.541 **Project Justification:** By this time the proposal reader has a pretty good idea of the need for, and the nature of, the proposed technology. Therefore it is an important time to drive the argument home with a strong "project justification." The **project justification** is a succinct

Why do we need to "justify" the project?

statement of the social, economic or political advantages for conducting the project. In our UHF Radio Receiver project we might cite economic reasons, like the amount of financial losses from property damage caused by tropical storms. We could cite the number of people annually made homeless by storms; and the attendant costs to government for resettling these people.

6.542 Two rules for this brief section of the proposal are that it should be succinct; that means it should be clear and brief. Further, it should be persuasive. Persuasiveness is a ticklish matter. Many scientists interpret persuasiveness in terms of technical or research arguments. They overlook the fact that many of the readers of R&D proposals are not technical people. More often they are government bureaucrats who have only a layman's knowledge of science and technology.

Why is "persuasiveness" important?

6.543 Persuasiveness is achieved by writing arguments that are meaningful to the reader—that is, arguments based on social need, political expediency or economic opportunity.

6.551 **Scope and Limitations:** In the early part of any project proposal it is easy to leave the reader with the impression that the proposed project will solve all the problems described in the discussion of national development needs. Frequently our anxiety to acquire funding and support for a good project will lead us to overstate, or oversell, the merits of the project.

These are not reasons why the project will not succeed.

They are clarifications of what the project will, and will not, achieve.

6.552 This section of any project proposal is designed to present the very real limitations, whether internal or external, technical, managerial, resource, or other, of the project. It is an opportunity to align everyone's expectations about what can be accomplished on the project—as well as what cannot.

Why should we bother to tell anyone what the project will not accomplish?

6.553 These are not reasons why the proposed project may not be successful. On the contrary, we must design a project which, if properly resourced, has a high probability of success. Rather, these are adjustments and refinements of the readers' expectations of just what the project will achieve. We do not want to mislead anybody about what

we expect to accomplish through the expenditure of public funds.

6.554 Rather than detract from the inherent persuasiveness of the proposal, this section frequently enhances the credibility of the technical people who will conduct the work—thereby reassuring the reader that they are not flying in the face of unrealistic optimism. Here is an example taken from our fictitious UHF Radio Receiver project:

How can a list of project limitations enhance the persuasiveness of the R&D proposal?

Scope and Limitations of the Project

... not practical to fulfill all the requirements for the UHF Radio Receiver. For example, solar energy technology is not sufficiently developed to provide power for the unit under the overcast conditions which accompany torrential downpours during this country's rainy season.

Two other characteristics, however, will compensate for this deficiency. Nickel-Cadmium technology for storing electrical energy is well developed—thereby affording us the opportunity to exceed the requisite unregenerated running time. Further wind generation, a well developed technology, will more than compensate for lack of solar capability because most of the regions to be served by the unit experience a minimum wind speed of 5 km/hr, year around (the lower threshold required for efficient generation of electrical power).

6.561 **Methodologies and Procedures:** This is the section in which the basic technological methods and procedures for this project are laid out. This should be written for the nonscientific reader—e.g., the government administrator who will advise Cabinet Officials about project funding priorities.

6.562 It is a good place to introduce the project tasks which will, later, serve as the principal units for planning and budgeting. They can first be introduced in a list; then described separately so that the reader obtains a pretty good idea of what happens in each one.

We developed the task list during the planning process. So which came first, the plan—or the proposal? How do they relate to each other? Who develops each of them?

6.571 **Role of Project Beneficiaries:** Throughout this course of instruction we have frequently alluded to the importance of including “beneficiaries” or “end-users” in the R&D process. This is too often ignored by government RDIs, around the world. It is more often done by private, for-profit, RDIs because their very existence depends on the satisfaction of clients.

Summarize the role of R&D beneficiaries (“end-users”) in the R&D process—from project inception, through research, development and implementation of results.

6.572 We have discovered that technologies which are researched and developed with full participation of beneficiaries, are most often fully adapted, applied and integrated into the production processes of the national economy.

6.573 Therefore, we are here recommending that each and every R&D proposal contain a brief section which specifies the role of target beneficiaries in the R&D process. This includes everything from needs assessment before a project is planned, to impact evaluation after the derived technology has been disseminated.

6.581 Scheduling and Summary of Workplan:

A natural follow-up to the discussion of project tasks is project schedules. For example, a simple bar chart which arrays tasks over time will help introduce the time element to deliberation about this project.

What other techniques could be used to show the relationships among project tasks, and schedules.

6.582 During this discussion it is important to emphasize any time considerations which impinge on the project but are not under the control of the project. For example, the upcoming rainy season with its attendant damages to people and property adds incentive to get the UHF Radio Receiver project underway as soon as possible. A possible time constraint that is worthy of mention could be the time required to import certain parts, or technologies from abroad.

Highlight possible delays in the project which are beyond the control of anyone in the RDI.

Especially highlight those which are within the control of other agencies, related to, but separate from the RDI!

6.583 After a discussion of the major facets of scheduling, this section should conclude with a refined Workplan. This is a good place to include a Bar Chart, or a Deliverables Chart. But it should be accompanied by sufficient words for a naive reader to interpret it accurately.

6.591 Facilities, Organization and Personnel:
This is where we begin to note other resources which will be required to complete the project. It is also a place to highlight those RDI capabilities, equipment, facilities, and specialized personnel, which make this project particularly well-suited for this institute.

What are the RDI's unique capabilities to conduct this project?

What is the management plan for the project?

6.592 It is the beginning of the discussion on how the project will be managed. What laborat-

How will costs be monitored and controlled?

ories will be involved; what personnel; who will be the key project technical people; where will the responsibility for project control fall? These are some of the issues raised in this section.

How will scheduling and technical performance be controlled?

6.593 Again, it is not important to be comprehensive. It is important to be informative and to highlight the most salient considerations for project selection purposes.

6.601 **Budget:** Finally, we come to the budget section of the proposal. This is the budget which we derived earlier. It is the basis for funding requests of higher levels of management. It is particularly important to highlight the capital budget.

This is the budget we developed earlier. Which comes first, the budget or the project proposal?

6.602 After the project has been approved, on the basis of this proposal, and funds have been allocated, it will most likely be necessary to redesign the project's working budget. This is because few RDIs are able to provide the same amount of funds as requested for R&D projects. So project schedules, or even deliverables, may have to be altered—requiring a commensurate change in financial flows and totals.

What is their relationship? Who develops each?

6.61 **Expected Outcomes of the Project:** By this point in the proposal, the reader has become immersed in numerous details of the proposed technology, and the R&D processes. Here is a useful place to recapitulate, for them, the expected products which will result from the R&D activity. It need not be, indeed should not be, discursive; because, all of it has been said before. In fact, a concise listing of expected end products with one or two sentences describing each one may suffice. This section helps the reader keep their mind on the ultimate goal and impact of the proposed project.

Why is it important to add expected outcomes of the R&D here—especially when it was said earlier in the purpose statement of the proposal?

6.621 **Dissemination and Transfer to Beneficiaries:** This element is too often ignored by R&D proposal writers. It is designed to answer the question, "Well, how will you get the technology out of the RDI and into the hands of the people who should benefit most from it?" This is a very important question because it turns out that the requirements of dissemination and transfer can

How many of the R&D proposals currently in your RDI talk about how the new technologies will be transferred to the beneficiaries?

have a profound effect on the character of derived technologies.

6.622 For example, a UHF Radio Receiver which requires the user to have a degree in radio electronics is far less practicable than one which requires no training for the user at all. In the agricultural sector, R&D which requires transfer through extension workers is acceptable where such an outreach system is in place. But what about a country in which the extension service is poorly organized and under-staffed?

6.623 This section of the proposal should outline, briefly, the characteristics of dissemination and transfer of derived technologies to the intended users. It should conclude with language about the influence of dissemination methods on the technical qualities of the proposed work.

6.631 **Other Pertinent Information:** This is an opportunity to say anything which may enhance the proposal; or at least which should be part of other managers' consideration as they select projects for the RDI portfolio.

What kinds of information will your RDI research leaders have to include in this section?

6.632 This information may relate to national development needs; technologies; resources required; deliverables; project management; or anything else. It is a good place to highlight particularly advantageous considerations about the proposed project. It is a good place to, again, recapitulate the project justifications.

What other information is important for the consideration of project proposal readers?

6.633 Finally, the APPENDICES of the proposal may incorporate a variety of important details. They may be technical-results of pertinent studies; data on user needs; feasibility study reports; glossary; instrumentation; bibliographies; or other types of information. It is important that these inclusions be meaningful to the reader who wishes to probe deeper into the details of the proposed work.

What are the criteria for deciding whether a particular piece of information should be in the APPENDIX or in the main body of the proposal?

6.641 **Summary:** Yes, this too, is a vital element of any good project proposal. It should be written last—that is, after you have all the data necessary for the other parts. It should comprise 3–5 pages and should be appended right up front—after the

Who is the target audience for the proposal summary?

title page and table of contents. That way it is front-and-centre for those busy bureaucrats who have no time to read more detail.

6.642 Needless to say, this summary should overview the proposed project, starting, again, with the national development needs. It should highlight project objectives and deliverables; significant technologies; particularly compelling management issues; and resource requirements. It should close with a reiteration of the national development needs which will be addressed by the outcomes of the project.

6.643 **Case 1** presents the recommended contents of project proposals forwarded by R&D personnel of an industrial RDI in Eastern Africa. Notice that while they differ in sequence from the contents we have just advocated, they offer the same overall information. In a foreword to this prescription, the RDI director states:

It should be clearly understood that there is no rigid formula for writing a project proposal and that the format presented here is a guide which can be modified suitably to reflect the ingenuity of the author, and the requirements and expectations of potential sponsors of the project.

6.644 This particular RDI conducts some projects for clients in the private sector. That is the reason for the last admonition:
 "...requirements and expectations of potential sponsors of the project.

6.645 But it is equally valid for those RDIs who conduct R&D at the behest of government alone. In this case, government is the "sponsor" or the client. And, as I am sure you can testify, government has its special tastes and preferences for the manner in which information is submitted to it.

6.646 So the point is that while all R&D proposals will probably have the same kinds of information in them, the format and presentation of that information should adapt to the special characteristics of the R&D clients and sponsors, technical specialists, technical goals and objectives, and management requirements.

What information should be in the summary? Where should it appear in the proposal?

Case 1: INDUSTRIAL RDI PROJECT PROPOSAL OUTLINE

An industrial RDI developed some proposal standards in 1981 which have dramatically eased the burden of R&D project selection because they are:

- uniform for all projects*
- comprehensive in information they provide*

Their outline is as follows:

- 1. Title: it must be descriptive of the project.*
- 2. Introduction: a brief explanation of the problem, its importance and scope.*
- 3. Objectives: of the project (focus on outcomes).*
- 4. Background: to the project; including previous related work.*
- 5. Justification: social and economic benefits; and technical merits of the project.*
- 6. Work Programme: logical sequence of R&D tasks, plus schedules and staffing.*
- 7. Costs: personnel (plus overhead); capital equipment; stores and services; communications; travel and transport.*
- 8. Conclusion: Summary plus future trends and possibilities.*

6.711 **Proposal Reviews:** Some RDIs go through elaborate review processes for their annual crop of R&D proposals. Others do not. It depends on the quality of work done in the RDI, the amount of control that is desired, the type of technologies involved, time available, and the management styles dominant in the RDI.

6.712 Suffice it for us to encourage all RDIs to develop some limited capability for technical directors to obtain peer reviews of their proposals, during the drafting process—i.e., before they undergo final evaluation for project selection and funding decisions.

6.721 **Peer Reviews:** Peer reviews are those conducted by people who are equal to the proposal writers in either, or both, of two characteristics: technology and management capability. Both perspectives will help the writers hone the proposal to its most communicative essentials. Their “peer” qualities will enhance reviewers’ credibility as critics for the proposal writers. They will also remove the threat of penalties for unsatisfactory work.

6.722 The purpose of peer reviews is to derive improved project or programme proposals (or reports). In other words, all participants must commence a peer review with the general belief that all work can be improved; and that each “peer” has a point-of-view which is worth consideration. In other words, a peer review should take the form of a discussion of a work’s strengths, and opportunities for improvement, among colleagues.

6.723 Other review practices may be adopted. For example, some RDIs annually develop a panel of “external” reviewers who examine all proposals coming from the institute in a year’s time. Their use of external peers is an attempt to ensure some objectivity in the selection of projects for the RDI portfolio. Other times it may be an attempt to build-in to the review process, technologies and expertise which are not present in the RDI staff.

Should a project proposal contain a debate of the technical merits and demerits of alternative methodologies considered for the project? Why, or why not?

Should a project proposal contain a summary of the technical literature related to the subject of the project? Why, or why not?

Who regularly reviews project proposals in your RDI, prior to their final submission?

What criteria do they apply in their reviews? What are they looking for? Why are they looking for that?

How could the proposal review process in your RDI be changed to improve the quality of R&D proposals?

6.724 But whatever your review practices, develop and standardize some. Reviews are healthy, educational, and beneficial for the whole institute. They go a long way toward keeping the institute's work goal-oriented and of the highest technical quality.

Exercise 1: Designing an RDI Project Proposal Process

The purpose of this exercise is to not only review the material we have just covered, but more significantly, to adapt it for application to your own RDI. Therefore, it requires that you think about your own RDI and its particular needs for the kind of project management capabilities provided by R&D project proposals.

The exercise will be done in teams of two participants. Each team member will be acting as colleague and consultant to the other. It helps to be able to talk some of these ideas out with another R&D manager—particularly if they are not from the same institute. Therefore, make sure your partner comes from another RDI—they need not even represent the same technical speciality, or sector.

The object of the exercise is to design a project proposal process for your RDI. The RDI may already have one; that is great. Maybe it can be improved through your efforts now. Let us see.

Following are two sets of questions: diagnostic and process design questions. You and your partner should go through the first set, discussing your respective RDIs for each one. They should give you a pretty good idea of ways in which your RDI project proposal process may be improved.

Your answers to the diagnostic questions should also prepare your partner for helping you design the optimum proposal process for your RDI.

All the design questions should then be answered for each RDI, separately. Go through all of them for the first RDI. Then discuss the optimum proposal process for that RDI. Then repeat the design questions for the other RDI and discuss the optimum process for it.

Now discuss the similarities and differences in proposal processes between these two RDIs. Why are they different?

Finally, on the blank page provided at the end of this section, write the details of the project proposal process which you and your partner think would enhance R&D management in your RDI. We have provided five elements for your description, at the end of these instructions.

(Exercise 1: Continued)

[Instructor(s): Read these instructions aloud—making sure they are fully understood. Do the same with the diagnostic and design questions. Assign partners in a manner which is most satisfactory to all—making sure no teams have individuals representing the same RDI. Recommend and monitor 20 minutes for the diagnostic questions discussion. Grant the same time for the design questions. Leave 10 minutes for the write-up. Encourage teams to share their own answers with their partners, in order to stimulate any last-minute improvements. Ask for volunteers, or select individuals to present, in plenary, their designs and the reasons for them.

Diagnostic Questions

1. Are project proposals regularly written in this RDI? Why, or why not?
2. Is there at least one proposal for each project?
3. Who writes them? Who reviews them before completion? Who receives them?
4. What information is in them? Why are they written?
5. Who uses them? What decisions are based on them?
6. Is their content standardized throughout the RDI? Format too?
7. How do RDI staff feel about the proposals? About the writing process? About the review process?
8. What happens to proposals after R&D projects are selected and underway?

Design Questions

1. What are the principal sources of information for project selection purposes in your RDI?
2. What are the principal sources of information for project planning purposes in your RDI?
3. How can project proposals enhance project selection, planning, implementation, monitoring, control and evaluation in your RDI?
4. What kinds of information should be in a project proposal to provide increased project management effectiveness?
5. Who should be involved in writing and reviewing project proposals? Why?
6. How often, and when, should project proposals be written, reviewed, and revised?
7. To whom should project proposals be distributed; when; and why?

Elements of a Project Proposal Process

- A. Purpose and use of project proposals.
- B. Contents and format for project proposals.
- C. Writers and reviewers of project proposals.
- D. Frequency and cycle for developing project proposals.
- E. Distribution of completed project proposals.

Use these five elements as an outline for your description of the optimum project proposal process for your RDI. Write it on the next page. Then read it to your partner. Ask for any ideas for last-minute improvements. Volunteer to share your design with all the other workshop participants during a plenary discussion of the exercise.

(Exercise 1: Continued)

PROPOSING: Selected readings for more study

- Allen, D. H. "Credibility and the Assessment of R&D Projects". *Long Range Planning*, Vol. 5, No. 2, June, 1972, pp. 53-64.
- Allen, J. M. and K. P. Norris. "Project Estimates and Outcomes in Electricity Generation Research". *Journal of Management Studies*, Vol. 7, No. 3, October, 1970, pp. 271-287.
- Avery, R. W. "Technical Objectives and the Production of Ideas in Industrial Laboratories". Unpublished Report, January, 1959.
- Baker, N. R. "R&D Project Selection Models: An Assessment". *IEEE Transactions on Engineering Management*, Vol. EM-21, No. 4, November 1974, pp. 165-171.
- Baker, N. R. and Freeland, J. R. **Recent Advances in R&D Value Measurement and Project Selection Methods**. Presented at the 41st National Meeting of the Operations Research Society of America, New Orleans, Louisiana, April, 1972.
- Baker, N. R., Jack Siegman and Jon Larson. "The Relationship Between Certain Characteristics of Industrial Research Proposals and Their Subsequent Disposition". *IEEE Transactions on Engineering Management*, Vol. EM-18, No. 4, November, 1971, pp. 118-124.
- Bell, D. C. **The Evaluation and Selection of Research Projects**. Gas Council Operational Research Department Report ORR/II, England, 1969.
- Brandenburg, R. G. "Project Selection in Industrial R&D: Problems and Decision Processes". In *Research Programme Effectiveness*, M.C. Yovits, et al., eds., New York: Gordon & Breach, Science Publishers, Inc., 1966.
- Cooper, R. G. "An Evaluation System for Project Selection". *Research Management*, Vol. 21, No. 4, July, 1978, pp. 29-33.
- Pacifico, C. "Is it Worth the Risk". *Chemical Engineering Progress*, Vol. 60, May, 1964, pp. 19-21.
- Schlicksupp, H. "Idea-Generation for Industrial Firms—Report on an International Investigation". *R&D Management*, Vol. 7, No. 2 February, 1977. pp. 61-69.

*MANAGEMENT MANUAL FOR PRODUCTIVE R&D:
R&D STRATEGIC AND PROJECT PLANNING AND BUDGETING*

CHAPTER VII

MONITORING AND CONTROL

MONITORING AND CONTROL

Training Objectives

By the end of this chapter, the participants will be able to:

1. Define and explain the purpose of R&D monitoring and control.
 2. Explain the relationship between R&D planning, budgeting, monitoring and control.
 3. Identify the three principal components of R&D programme performance.
 4. Explain the six steps for monitoring and control.
 5. Explain five assumptions which underlie monitoring and control.
 6. Define and describe control points for time, cost and technical performance.
 7. Design an R&D project performance review process.
 8. Interpret rate-of-completion graphs.
-

MONITORING AND CONTROL

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All of this material could be covered in one session, if it has been studied on an individual basis prior to the session.

CHAPTER VII

MONITORING AND CONTROL

We can plan an R&D project; we can budget for it too. We can propose R&D projects and select from them those which will go the furthest in enhancing national development. We can even evaluate, after a period of time, to see if the project had the desired impact on national development. But what can we do between selection (at the beginning of the project) and evaluation (at the end) to ensure that the project progresses the way it should; and, has the desired impact on national development?

7.11 **Introduction:** Project planning is like laying out the route, on a map, before we commence a long trip by automobile. Budgeting for a project is like collecting all the clothes, food, sun glasses, tools, cash, checkbook, and any other resources we may need on the trip. Project selection and implementation is like getting in the automobile, starting it up and putting it in gear.

7.12 Now if our plans (carefully selected route) are good, and if our budget (food, fuel, cash, etc.) is accurate, then our R&D project should be successful; right?

7.13 Project evaluation is like having someone at the destination to see if we actually arrive in time, and within resource constraints. Well, would the automobile arrive at our destination, on time and within food and fuel limitations if we laid out the best route, and provided sufficient supplies?

PLANNING

+

BUDGETING

+

SELECTION

+

IMPLEMENTING

+

?

+

EVALUATION

=

R&D MANAGEMENT

7.14 Of course not ! Why not; what more is needed? What about an R&D project? Would it accomplish all technical objectives within time and resource limitations if it were well planned and budgeted? Why not? What more is needed?

7.15 Someone has to steer the automobile throughout the entire route. They have to select the proper detours when road repairs are encountered. They have to replenish the fuel supply by anticipating when the tank is low. They have to change a flat tyre and make any other unexpected adjustments to the automobile. They have to adjust to unanticipated weather patterns which interfere with safe driving conditions.

7.16 In short, they have to monitor all the driving conditions, including intermediate destinations, time and resources, status of the automobile and of its passengers. They have to make a variety of adjustments to everything involved in order to control the trip, i.e., to see that the final destination is reached in a safe and timely fashion.

7.21 **Definition:** Monitoring and controlling an R&D project is like driving an automobile on a long trip. **Monitoring** an R&D project is the process of observing project progress and resource utilization, and anticipating deviations from planned expectations. **Controlling**, on the other hand, is the process of making adjustments which correct for the deviations from planned progress.

Of what use is a good plan, if you do not try to adhere to it?

How can you adhere to a good plan if you do not track your progress?

7.22 We include a unit on monitoring and controlling R&D projects, in a workshop on "Planning and Budgeting" because the principal use of plans and budgets occurs during project implementation. Plans and budgets are designed to help us expect productive R&D. Monitoring and controlling project implementation help us realize our expectations (or, occasionally change our expectations).

Why do we need good plans and budgets for R&D work?

What do we mean by "good?"

7.23 This unit will only introduce the principal concepts and processes of R&D project monitoring and control. Other manuals will have to provide more detailed training in monitoring and control.

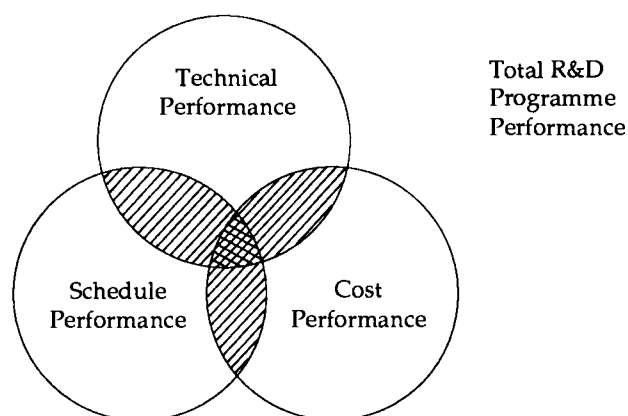
7.311 What is Monitored and Controlled: The answer to this lies in the answer to the question: "What is planned, in an R&D project?" Back in the unit on **Planning** we "planned" the technical elements of the project—called tasks. We planned their completion over time; and we planned their cost. Those are the principal elements of any R&D project monitoring and control system.

What three things have the greatest influence on R&D productivity in your RDI?

How do each of them relate to R&D plans and budgets?

7.312 They are also the principal requirements for R&D productivity aren't they? We have to have some technology; time to work with it; and, resources needed to fuel the process. **Figure 1** depicts the three principal elements of an R&D project monitoring and control system.

Figure 1. Three Elements of R&D Project Monitoring and Control



Total Programme Performance = R&D Productivity } Why?

7.321 R&D Productivity: We monitor and control R&D projects for the same reason we planned and budgeted them—to increase the favorable impact of R&D on national development needs. Monitoring and control, like all other elements of R&D management, are servants to R&D productivity. As the intersection of all three circles in **Figure 1** shows, R&D productivity is the heart of the matter.

7.322 In the case of monitoring and control, it means that all tasks of the project (technical performance), were completed on time (schedule

performance) and within resource constraints (cost performance).

7.33 Technical Performance: It is not enough to accomplish the tasks of a project. That alone does not yield R&D productivity. Because, what if it takes twice as long as we expected to do it; or it requires major cost overruns? It is not enough for an RDI, or technical people, to achieve the technical performance standards without considering time and costs.

How well do all technical aspects of the RDI perform? This includes technical people, instrumentation, facilities, services, and so on.

7.34 Schedule Performance: Nor is it sufficient to achieve technical objectives of a project within the time limitations specified in project plans—remarkable as that achievement may be! In truth, doing that may require fantastic cost overruns. For example, the RDI might have to hire twice as many laborers as planned to accomplish all tasks within project time constraints. Such a labour pool would rapidly exceed financial resources.

Are facilities ready on time?

Do the personnel arrive on time?

Do parts and supplies arrive on time?

Are tasks performed on time?

Are results analysed in time?

7.35 Cost Performance: Similarly, good technical performance, within cost constraints, is an insufficient guarantor of R&D productivity. This is because time was ignored. All three elements have to be monitored, and controlled, simultaneously. The tasks have to be accomplished within time and cost parameters—whatever those parameters may be.

Is the R&D programme/project on time?

What are personnel costs?

What are supply costs?

What are overhead costs? When are monies spent?

7.361 Changing the Parameters: The technical, schedule and cost parameters are detailed, first, in the project proposal. Then after the project is selected for resource allocation and implementation, a working plan is devised for the project. At this time the budget is also revised to reflect the most realistic expenditure of available resources.

Is the project/programme cost and rate of expenditure, as planned?

7.362 As soon as working plans and budgets are completed the project technical, schedule, and cost parameters are set—for the life of the project, right? Wrong! They are set, but not necessarily for the life of the project. In fact, changing the parameters is one very effective way of controlling project performance.

If the plan is not good; change it!

But if the project or programme is being poorly managed, change the management of it!

7.363 By definition controlling is making adjustments so that the project performs according to our **expectations** (see the definition on the second page of this section). Our expectations are established by the project plans and budgets. If monitoring shows that a particular project is deviating from planned (expected) parameters, then one way to control it is to change our expectations; in other words, re-plan the particular parameters involved.

What do we mean when we say, "deviation from expected performance?"

7.364 This is a perfectly legitimate control strategy, as long as it is not abused. For example, it may be that a project is experiencing cost overruns because of poor control over expenditures by project management.

7.365 It would be a mistake to re-budget, showing more funds available to compensate for overspending, but at the same time under-allocating for subsequent technical work. When a monitor reflects a significant deviation from planned parameters, it is important to analyse the source of the deviation before deciding what control measure is appropriate.

7.411 **Monitoring and Control Steps:** There are six steps in monitoring and controlling R&D projects. We have already talked in detail about some of them:

- Planning
- Allocation
- Execution
- Measurement
- Evaluation
- Adjustments

These should sound fairly familiar by now. But, who do you think should be responsible for each of them in monitoring and controlling an R&D programme or project?

Hint: There is only one answer to that question!

7.412 Defining technical tasks, scheduling them and budgeting financial resources comprise what is meant by planning. Planning establishes the expectations against which we monitor and control project performance.

7.42 **Allocation:** This simply refers to the application of financial and other resources, once the project has been selected for inclusion in the institute portfolio. Allocation has taken place when project managers are told they may proceed to

Here are 7 standard management activities:

- planning
- organizing

expend RDI resources on executing the technical work.

7.431 **Execution:** This means doing the technical work specified in the project plan. Naturally it requires resources like people, and others.

7.432 Execution leads to technical performance. Whether it is achieved within planned parameters is partly a function of the time and money available. But it is also a function of technical conditions—some of which may not have been anticipated through planning. This is not an infrequent occurrence, particularly in R&D work.

7.44 **Measurement:** This word is almost synonymous with “monitoring”. It means systematically watching performance on all parameters in order to detect the earliest available signs of any deviations from planned performance.

7.451 **Evaluation:** Let us face it, even the most experienced R&D planner must act, sometimes, like a prophet or seer. They must be able to predict a whole range of performance parameters on an R&D project which has never ever, been done. So it is not surprising when some performance characteristic begins to show some deviation from plans.

7.452 Evaluating performance deviations from planned parameters is difficult. By comparison, planning is easy. Evaluation is the task of (1) deciding when performance is deviating from expectations (not always an easy thing to do); (2) determining whether the deviation is within acceptable norms; and (3) analysing the causes of the deviation.

7.46 **Adjustments:** Once it has been determined that some aspect of the project is deviating too far from expected parameters, then it is the job of project management to exert some influence on that aspect—or change the parameters. Usually some adjustment can be made in resource availability or scheduling. Sometimes, a new technical activity must be initiated. These are R&D “controls”. These are the tools available

- staffing
- directing
- monitoring
- controlling
- evaluating

How do they compare to the 6 steps in monitoring and controlling?

What are the differences and similarities?

Is performance deviating?

Is the deviation within acceptable limits?

Why is it deviating?

If the deviation is not acceptable, should something be done about it?

Project/Programme Evaluation

Who does this kind of evaluation in your RDI?

How do they do it?

Why do they do it?

Who makes decisions as a result of such evaluation?

to help ensure that the project actually performs as expected.

7.511 Assumptions: There are some critical assumptions underlying any monitoring and control system. It is important to assess them in each R&D project because if any of them are not true, then monitoring and control is impossible.

DO YOU AGREE WITH EACH OF THESE?

7.512 Monitoring and controlling any R&D project is based on the five assumptions that:

- Project performance can be measured
- Personal responsibility for the performance of the project exists
- Time required to monitor and control is worthwhile
- Deviations and mistakes can be discovered in time
- Corrective action is possible

YES

NO

☐
☐
☐
☐
☐
☐
☐
☐
☐
☐

7.513 We have already suggested that measuring performance is difficult in the best of circumstances. But two other assumptions are even tougher to fulfill. Personal responsibility for performance of a project is sometimes hard to find.

WHY, OR WHY NOT?

7.514 This is where a lot of those other management issues like bottom-up planning, organization structure, and management style come into play. R&D people are not different from all others. They like to take pride in their work—particularly since it requires so much creative energy. As a consequence, they must feel like they have some control over their work—that they have a significant amount of influence over what they do.

7.515 If these are characteristics of R&D managers in your RDI, then personal responsibility for monitoring and controlling R&D projects exists. If not, then it does not.

Why is it so hard to find personal responsibility for performance of an R&D project or programme, in an RDI?

7.516 Whether or not the time required for monitoring and control is warranted depends, in part, on the effectiveness of the controls in ensuring R&D productivity. And, whether or not performance deviations can be discovered in time to exert significant control on the project depends, in part, on the sensitivity of monitoring devices. We will spend the balance of this unit talking about monitoring and control tools.

How does RDI organization and management style influence personal responsibility for R&D project performance?

7.521 **Monitoring and Controlling Time:** We said earlier that the origins of R&D project monitoring and control are in project planning. Let us see if that is true. Figure 2 probably looks familiar to you. It is a reproduction of a Deliverables Chart we developed for the UHF Radio Receiver project, back in the chapter on planning. Let us do an exercise with it.

Exercise 1: Monitoring Time with a Deliverables Chart

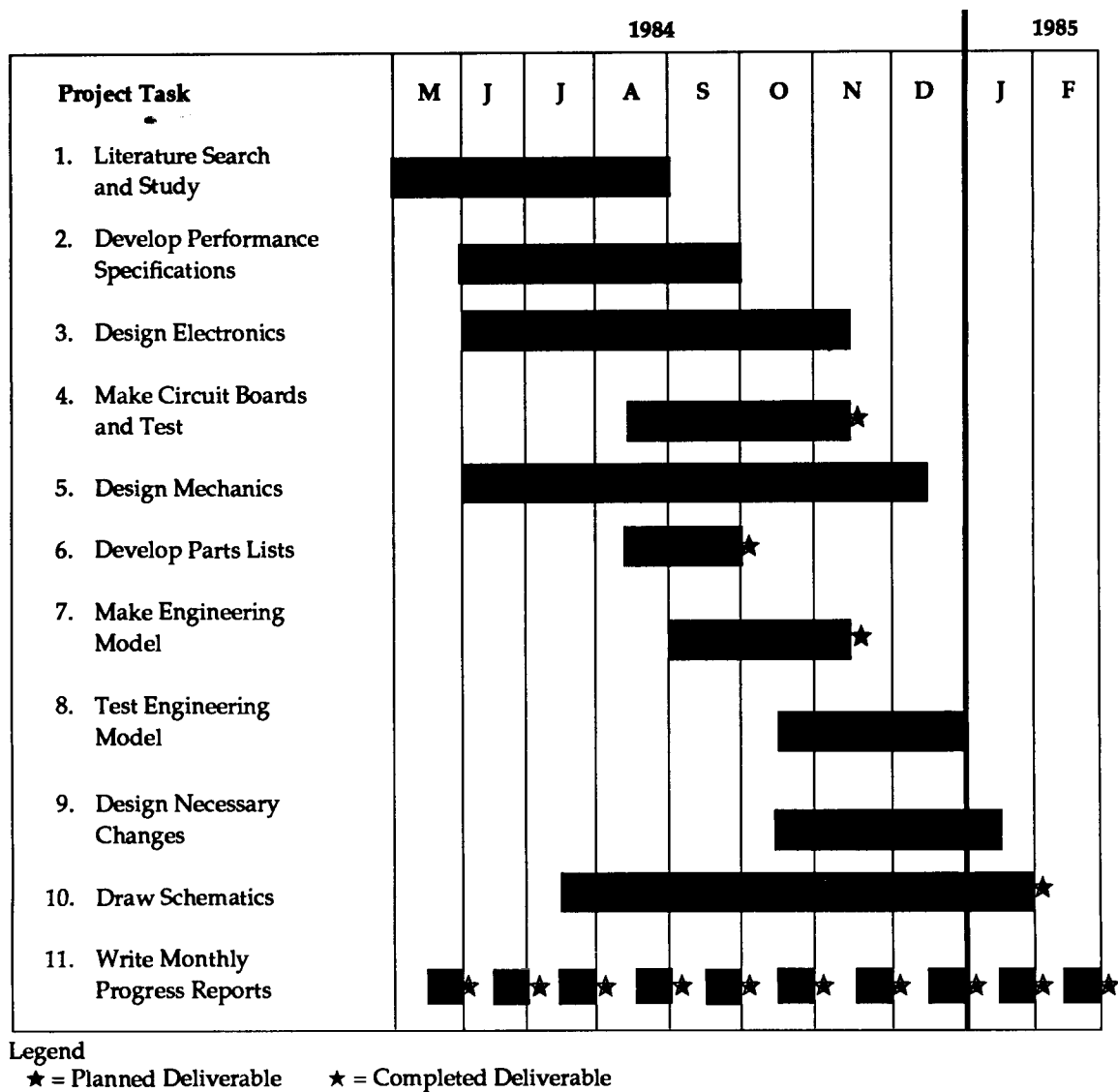
Take a look at Figure 2, on the next page, and answer the following questions:

1. What are the time elements of the chart?
2. What are the control points available on this chart?
3. What are the criteria by which we will evaluate schedule performance, using this deliverables chart?

DO NOT LOOK AT THE ITEM BELOW FIGURE 2 until you want our answers.

Figure 2. UHF Radio Receiver Project Deliverables Chart

Project Title: Development of a Production Model, and Specifications for a Marine Fisheries Ultra High Frequency (UHF) Radio Receiver



(Exercise 1: Continued)

OUR ANSWERS to the three questions:

1. The time elements are the monthly demarcations starting with the month of May and continuing through February.
2. The control points are all those particular times which are indicated by the beginning or ending of an activity bar, or by a star.

(Exercise 1 is continued on the next page)

(Exercise 1: Continued)

3. The criteria by which we will evaluate schedule performance are all those technical products or activities which are sufficiently discrete to identify during the performance of the project. If they occur at the control points indicated, then the schedule is performing as planned. If not, then it is not.
-

7.522 That is fairly straight forward. We monitor schedule performance by evaluating whether technical work is completed by the times predicted in planning exercises. Any of the networks we developed earlier could also be used for this purpose. But Analysis Bar Charting is particularly useful because it provides deviation tolerances—i.e., deviations which we can tolerate without exerting control on the project.

What is Analysis Bar Charting?

How is it different from a Bar Chart?

What does an ABC tell you?

7.523 But notice something. What if the technical work is not completed by the date predicted in the plan. Is it because the planners picked the wrong date—in which case all we have to do is change the schedule. Or is it because something is wrong on the technical end of the project? We are trying to monitor and control time, or schedule performance. But you can see that frequently it is very difficult to determine whether we are observing the effects of time, technical or cost performance. This is why we said earlier, that the evaluation stage of monitoring and control is so difficult.

7.531 **Using Costs as Evaluation Criteria:** Well, we got into some trouble when we used technical criteria to evaluate deviations in the project schedule. We could not tell whether the deviations were due to scheduling errors, or technical problems.

7.532 Let us take another crack at it using cost criteria to evaluate scheduling deviations. **Figure 3** has also been shown before. It arrays the UHF Radio Receiver project budget. How can it help us monitor schedule performance? Let us do another exercise.

Exercise 2: Monitoring Time with a Budget

Take a look at **Figure 3** and answer the following questions:

1. What are the time elements in this budget?
2. What are the control points available for monitoring time?
3. What are the criteria by which we will evaluate schedule performance, at the control points, using the project budget?

DO NOT LOOK BELOW THE FIGURE until you want our answers.

Figure 3. UHF Radio Receiver Project Budget

Tasks	M	J	J	A	S	O	N	D	J
Literature Search/Study	7.50*	3.29	10.00	7.00					
Dev. Performance Specs		14.50	23.50	42.20	11.184				
Design Electronics		17.00	23.00	7.50	11.00	28.00	4.50		
Mk/Tst Circuit Bds.				20.00	50.00	60.00	14.70		
Design Mechanics		6.00	14.00	12.00	11.70	17.00	16.00	3.00	
Dev. Parts List				2.00	3.00				
Mk Engineering Model					30.40	57.00	15.0		
Tst Engineering Model						48.84	73.26	24.40	
Design Necess. Changes						2.35	7.51	11.70	8.24
Draw Schematics			2.00	4.70	2.00	2.00	2.00	10.00	13.00
TOTALS	7.50	40.79	72.50	95.40	119.284	215.19	132.97	49.10	21.24
* x \$100 TOTAL PROJECT COSTS = \$75,397.40									

(Exercise 2: Continued)

OUR ANSWERS to the questions:

1. Once again, the time elements are the months of the project; they are arrayed horizontally in the first row of the table.
 2. The control points are the monthly costs.
 3. The criteria for evaluating schedule performance at these control points are three: (1) the total planned expenditure per month; (2) the total planned expenditure, per month, per task; and (3) the total cumulative expenditure per month (it does not show, but could be calculated from this table).
-

7.533 Now we have a fairly sound basis for evaluating schedule performance. If we find that the schedule is off, using both the deliverables chart and the budget, but that costs per technical performance remain as predicted, then we have a fairly decent basis for judging the schedule in error. Control may be as simple as rescheduling the project.

7.534 Thus you can see how planning and budgeting are key to effective R&D project monitoring and control. It is also possible to create some other schedule monitoring devices. But that must await another Manual.

7.541 **Monitoring and Controlling Costs:** There are also a wide range of cost monitoring and control tools. They, too, will have to await a **Manual on R&D Project Monitoring and Control**. Suffice it to say at this point that many of them are also based on a comparison of planned expenditures, and real ones.

7.542 Quite obviously then, we have to derive real costs during a project. This is part of the cost monitoring process. This work, called accounting, can be done by project personnel, or a relatively independent accounting department. But it is essential that it be done well by someone. Accounting plays a vital role in the management information system of the RDI.

Another "supportive" role for accounting and finance people.

But remember, they "support", not "direct", the R&D project management.

7.543 It is important that project people remain fully aware of project expenses, as they are

encountered—even if accounting is accomplished somewhere else in the RDI. Under these conditions, project managers may wish to develop a simplified accounting system which provides aggregated figures in special categories which are particularly liable to deviate and therefore, require closer control.

7.544 Again, the work done in planning and budgeting the project is the first step in monitoring and controlling costs. Let us take a look at an example. You have also seen Figure 4 before. It is our UHF Radio Receiver budget. Let us find out how it helps us monitor and control project costs.

Exercise 3: Monitoring Costs with the Project Budget

Take a look at Figure 4 and answer the following questions:

1. What control points are available for monitoring costs with this budget?
2. What criteria are available for evaluating cost deviations at each control point?

DO NOT LOOK BELOW THE FIGURE until you want our answers.

Figure 4. UHF Radio Receiver Budget

Tasks	Personnel	Special Services	Equipment	Material Supplies	Travel	Meetings Courses
Literature Search/Study	<u>\$18.99*</u>			8.00	0.80	
Dev. Performance Specs	20.00	<u>69.584</u>		1.00	0.80	
Design Electronics	32.00	55.00		4.00		
Mk/Tst Circuit Bds.	41.70	87.00		16.00		
Design Mechanics	37.90	36.00		3.50	2.10	0.20
Dev. Parts List	5.00					
Mk Engineering Model	18.00	49.00	<u>12.40</u>	23.00		
Tst Engineering Model	21.00	32.00	<u>88.00</u>	4.70	0.80	
Design Necess. Changes	29.80					
Draw Schematics	33.60			2.10		
TOTALS	\$257.99	328.584	100.40	62.30	4.50	0.20
* x \$100						
TOTAL PROJECT COSTS = \$75,397.40U.S.						

(Exercise 3: Continued)

OUR ANSWERS to the two questions:

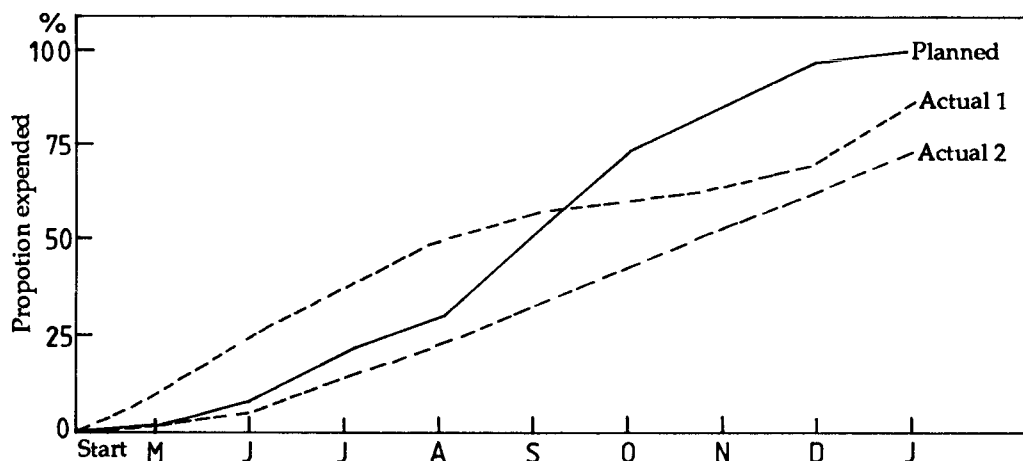
1. The control points available for monitoring costs with this budget are the categories of expenses, and the project tasks.
2. The criteria available for evaluating cost deviations are the total costs per category of expense, or per task.

7.545 It is also possible to use the other budget format for monitoring and control purposes (see Figure 3). For example, we could calculate actual expenditures by the end of each month of the project, and compare them to the planned expenditures.

7.546 Another technique is to standardize these numbers by calculating a proportion of the total expense for each month. We can then array a planned and actual rate of expenditure as in Figure 5. The solid line represents how we expect the expenses to behave, based on the budget. The broken line represents actual rates of expenditure (fictitious for the sake of this example). Take a look at the graph and answer the questions in Exercise 4.

Do you know how to calculate a proportion of the total expenditure for each month, based on the budget in Figure 4? If not, ask the instructor.

Figure 5. Project Planned and Actual Expenses



Exercise 4: Interpreting Cost Monitoring Graphs

Study the graph and answer these questions:

1. How were the control point proportions on the “planned” curve calculated?
2. How would you instruct your accountants to calculate the control point “actual” expenditure proportions?
3. Assume your performance on the project generated the curve for “Actual 1”. During which month did you experience the greatest cost overruns?
4. Which Actual curve represents the least total expenditure on the project? Explain.
5. Which actual curve represents the best cost performance? Explain. (Be cautious! You may be making assumptions about some things you cannot be sure about.)
6. What area of the curve represents deviation from the planned cost performance for Actual 2?
7. Which Actual reflects performance that has a better chance of completing the project, as planned? Explain.

DO NOT TURN THE PAGE until you want our answers.

(Exercise 4: Continued)

OUR ANSWERS to the seven questions above:

1. The proportions on which the planned curve are based represent the percentage of total allocated funds expected to be expended as of that date control point. They were calculated by summing the monthly totals from **Figure 3** up to that date and dividing by the total amount of money available for the project.
2. I would instruct my accountants to calculate the actuals in the same way. We would have to keep records of all real expenditures. Then at the end of each month I would have the accountant sum them and divide by the total amount of money available for the project.
3. The greatest cost overruns were experienced around the end of July. There, the Actual 1 curve deviates the farthest from the Planned curve, in the direction of more money spent.
4. Actual 2 represents the least amount of money spent on this project. It is important to remember, however, that this does not necessarily mean poorer schedule, or technical performance. Maybe the project team which generated Actual 2 knows how to get more work out of less money. Unlikely—but possible!
5. By “cost performance” we mean “closest to planned rate of expenditure.” Given that definition, neither Actual reflects particularly good cost performance. Actual 1 shows very poor cost control—going from severe cost overruns to severe underruns. Actual 2 showed much better cost performance during the first couple months of the project. But as the period continued, expenditures did not keep pace with the planned rate. Neither project used all of the money available. Ultimately, however, evaluation of these two curves should be combined with an evaluation of schedule and technical performance. For example, aside from cash flow problems brought on by Actual 1 during the July–August period, maybe both accomplished all technical work by the end of the period. In that case we would have to say that since Actual 2 did it for less money, then the Actual 2 project team showed greater efficiency. Notice that Actual 2 is a much more even slope. That, in itself, shows greater control—if all the technical work was completed.
6. The area of the graph between the Planned curve and the Actual 2 curve represents the deviation.
7. That is tough to answer without more information. But if we assume that the Planned rate of expenditure is well justified, and done by experienced R&D “prophets”, then we would have to assume that completion of the project will require 100% of the money. Actual 1 comes closer to spending that amount—so we would have to assume it comes closer to completing the project.

Is that how you would interpret this cost monitoring and control graph?

7.547 The important thing to remember when interpreting any monitoring and control data is that a graph like Figure 5 is only part of the picture. It only shows rate of expenditure. It does not say anything about actual technical performance. Yet technical performance has to be one of the most important criteria for evaluating R&D productivity. Therefore, during monitoring and control exercises, the project team has to look at measures on all factors simultaneously. Only then can they determine when and where management controls are needed.

What is rate-of-expenditure?

How is it calculated?

How does rate-of-expenditure relate to technical performance on a project?

It is wise to realize that the periodic budget is a primary financial tool for the control of certain aspects of R&D. In no way can it be considered a technical control, and even as a basic financial control it has several distinct limitations. It is useful in controlling the total funds to be spent, ensuring to a limited extent that resources are used on projects approved by management. But there is no foolproof method by which budgeting amounts and actual expenditures can be matched and the resulting variances interpreted as a measure of success or lack of success in R&D activity. (White)

7.551(a) **Monitoring and Controlling Technical Performance:** Somehow monitoring and controlling technical performance strikes technical people much less favourably than does monitoring and controlling schedules or expenditures.

Why? What can be done about this?

- Many engineers and scientists object to the requirement for monitoring technical performance.
- Many R&D projects depend on a test programme at their conclusion, to determine technical performance.
- Many engineers and scientists feel that they can make their own project work well without monitoring and control.

Are these true of your RDI also?

7.551(b) All of that notwithstanding, the chances of achieving success on any R&D project are much higher if technical performance is monitored and controlled.

7.552(a) Technical Monitors: Now some of the objections to monitoring and controlling technical performance may be allayed by placing the major burden for the activity on the shoulders of the technical people who are responsible for the work being monitored and controlled. This makes a lot of sense in another respect. These people usually have the best technical qualifications for the job.

Who should monitor technical performance?

7.552(b) Certainly these are the people who must ultimately exert control on the technical performance of the project. So it only makes sense to put the monitoring tools in their hands as well.

Who is in the best position to exert control on technical performance?

7.611 Performance Reviews: There are a lot of techniques available for this purpose. Many of them are very elaborate, graphical and quantitative. We will show you a couple. But before we do, consider one of the oldest, and most successful techniques for monitoring and controlling technical performance: the peer review.

7.612 A peer review simply refers to a group of R&D project team people, plus their peers from other areas in the institute (or from outside). The most significant criterion for "peer" is technical qualifications. They must have the technical capability of understanding the purpose, progress and prognosis for the project. A second criterion for "peer" which also may help is rank in the RDI. It helps if the project team is not threatened by the authorities of a "boss."

Has your RDI ever used the peer review?

7.613 If conducted intelligently, technical reviews consume very little time and require the generation of no data beyond those needed by the project team to manage their work properly.

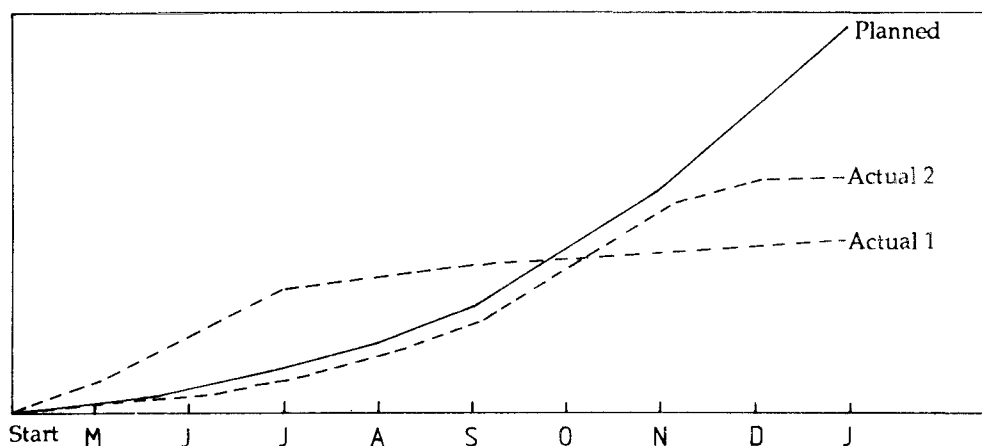
Relate your experiences with peer review to others in this workshop.

7.614 The technical "peers" review the purpose and relevance of the project; all work done to date; technical problems and opportunities encountered; and the path to completion. The peer review depends for its effectiveness on the technical qualifications of the "peers." What better measurements can you come up with?

7.621 Rate of Completion: A standard approach to monitoring technical performance is very much like the rate-of-expenditure technique

discussed in Exercise 4. It is based on the project team's ability to estimate a rate of completion over the duration of the project. In other words, the team has to be able to identify, in a valid and reliable fashion, what percentage of the project is technically complete at the control points (monthly intervals). Then a graph, similar to that in Figure 5 can be used to assess technical performance on the project. Here is an example.

Figure 6. Planned and Actual Technical Performance



Exercise 5: Interpreting Technical Performance

Examine the graph and answer these questions:

1. Which Actual reflects the best overall performance? Explain.
2. Back in August which Actual reflected the best overall performance? Explain.
3. Which reflects the greatest performance efficiency? Explain.
4. Which reflects the greatest performance deviation? Explain.

DO NOT TURN THE PAGE until you want our answers.

(Exercise 5: Continued)

OUR ANSWERS to the above four questions:

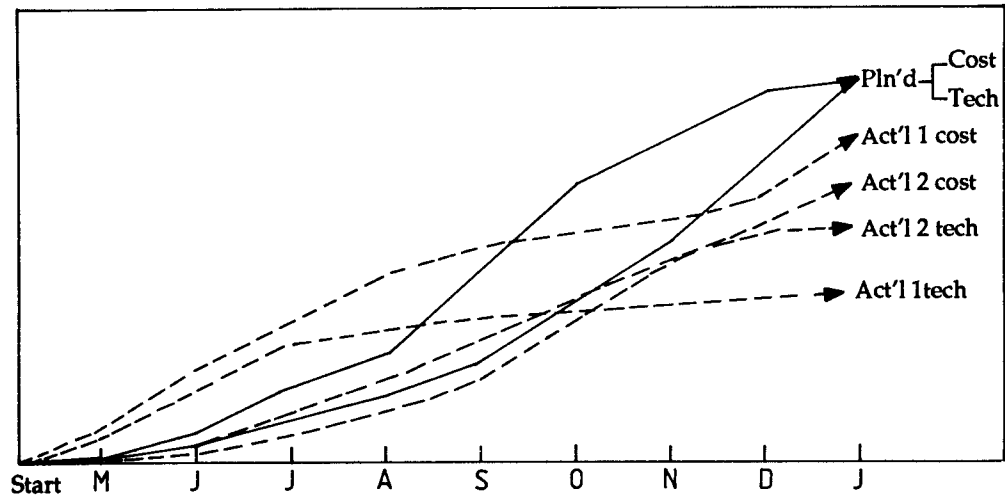
1. By the end of the project Actual 2 shows the best overall performance because it achieved closest to 100% of the project.
2. But back in August I would have said that Actual 1 was performing better since it actually achieved more than what was expected up to that time.
3. If we define "performance efficiency" as least deviation from the planned performance, overall, then we would have to conclude that Actual 2 was more efficient.
4. Actual 1 shows the greatest performance deviation from the planned curve—both during the first half of the research period, and at the conclusion of the period.

Is that how you would interpret technical performance from this graph?

7.622 Obviously, the trick to this method of monitoring technical performance is not interpreting the graph—but creating it in the first place. How, for example, can we get reliable estimates of the proportion of a project which is completed? A variety of techniques have been used: a panel of technical judges; a rating process; and expenditure of technical resources (raw materials, personnel, instruments and facilities, etc.). Completion is something which will have to be operationalized differently for each project.

7.623 An interesting capability afforded by this technique is that of comparing rates of expenditure and completion. This can be done since both are based on a common denominator—time. **Figure 7** shows a combination of these two deviation measures. Let us interpret it.

Figure 7. Monitoring Cost and Technical Performance



Exercise 6: Interpreting Cost and Technical Performance

Examine the graph and answer these questions:

1. Overall, which Actual (combination of technical and cost performance measures) reflects best project performance? Explain.
2. Which one shows greatest expenditure in August?
3. Which one shows greatest expenditure at the end of the period?
4. Which one shows greatest technical performance in August?
5. Which one shows greatest technical performance at the end of the period?
6. Which one shows the most favourable (smallest) cost per technical performance ratio in August?
7. Which one shows the most favourable cost per technical performance ratio by the end of the period?
8. Which one shows the best overall management? Explain.
9. How would you have answered that question in August? Explain.

DO NOT TURN THE PAGE until you want our answers.

(Exercise 6: Continued)

OUR ANSWERS to the nine questions above:

1. Overall Actual 2 showed best performance. It achieved more technical performance than did Actual 1; and it spent less money doing it.
2. In August the greatest expenditure was by Actual 1.
3. By the end of the period the greatest expenditure was by Actual 1 also.
4. In August, greatest technical performance was by Actual 1 also.
5. By the end of the period, Actual 2 showed greatest technical performance.
6. Hard to say without the data. But it looks like Actual 2 may have the lowest (most favourable) cost per technical performance ratio.
7. There is no doubt that by the end of the period, Actual 2 shows the most favourable cost per technical performance ratio. It achieved more, for less.
8. Actual 2 shows the best overall management. Even before the end of the period this was reflected in the close proximity of Actual 2 curves to the Planned curve.
9. In August this would have been more difficult to answer because Actual 1 showed greater-than-planned technical performance. However I would have been suspicious for a couple of reasons:
 - a. I put my faith in my planners. Until they alter their estimate, I expect my projects to adhere to the plan. If there is a deviation in either direction—I wonder why.
 - b. The ratio of cost to technical performance looks less favourable in August for Actual 1 than it does for Actual 2. That only reinforces my suspicions.

After all the data is in, I would have to conclude, either in August or certainly by the end of the period, that the management of Actual 1 overspent in order to compensate for some (as yet undetermined) problems on the technical end.

This is a classic pattern for a project which has severe technical problems but management keeps trying to compensate by adding more workers, or more materials, or more equipment—without carefully analysing and thinking-through the technical variables.

Is this how you would interpret this graph?

7.71 Planning and Budgeting: These are just a few of the principals and applications of monitoring and control in R&D management. They are meant to demonstrate the inseparable relationship between R&D project planning (which includes budgeting—the planning of financial resources), and monitoring and control.

Why is planning inseparable from monitoring and control?

How are planning, budgeting, monitoring and control integrated in R&D proposals?

7.72 Further, they are meant to reinforce the idea that planning (and budgeting), monitoring and control are all servants of R&D productivity. First we plan to be productive; then we monitor and control to ascertain that we are productive. Without that ultimate goal of productivity, why bother?

How do planning and budgeting relate to R&D programme, or project, selection?

7.8 Project Proposal: Further, the plan for a project should include specification of the control points for project management. This would be presented in the management discussion in the project proposal. It helps integrate the technical and management sections of the proposal. It also reinforces everyone's goal of producing useful results from R&D activity.

What impact does RDI organization have on planning, budgeting monitoring and control?

What impact do all these management functions have on R&D productivity?

7.91 Organization: Finally, organization lies at the heart of any RDI's success in planning, budgeting, monitoring or control. The secret for all these techniques is to conduct them in a manner which ensures the productivity of R&D projects, programmes and people. Too often, RDIs get caught up in an organization structure which is designed to perpetuate management.

7.92 One way to safeguard against this eventuality is to keep management responsibility, and the tools that go with it, in the hands of the R&D project technical managers. All RDI non-technical management personnel, should be in the service of R&D technical people. Too often, the reverse happens; RDI managers begin to think of technical people as servants.

7.93 It is a difficult, but vital balance which must be struck. Effective RDIs are those in which most resources, roles and responsibilities are vested in R&D project and programme leaders. After all, these are the people who play the most direct role in generating the output of the RDI.

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GLOSSARY

Glossary

ABC:	Analysis Bar Charting is a combination of the bar chart and networking approaches to planning. It can be very useful for calculating actual dates for commencement and completion of all tasks in a project, as well as isolating the critical path (see: CPM).
accounting:	the administrative task of recording actual costs and expenditures so that comparisons may be made to budgets (planned costs and expenditures) for the sake of financial control.
aggregation:	the summing or adding together, of various elements of a budget; to present a more comprehensive estimate of RDI cost.
allocation:	the actual supplying of money so that R&D work may commence.
applied research:	the application of science and engineering to the development of new knowledge, new techniques, or new products of economic value to society.
appropriation:	the decision to set aside money for R&D purposes; usually made by that government agency, or granting body, which controls financial resources for R&D.
bar chart:	a planning tool which shows the start date, stop date and duration of R&D tasks which comprise a project—by means of a two dimensional array which depicts tasks on the vertical axis and time on the horizontal. Matrix data are comprised of lines or "bars".
basic research:	fundamental application of scientific inquiry to understand the unknown and contribute to general knowledge.
bottlenecks:	like the narrow neck of a bottle through which all contents must pass, a "bottleneck" in planning terms is that time in the course of an R&D project during which so many activities and task components converge on a single moment that resources, like labour, are severely taxed.

budgeting:	the process of anticipating the costs, and planning the expenditure of financial resources for the execution of R&D tasks, projects and programmes.
capital budget:	the plan for expenditure of money for the purchase of major equipment, facilities and real property.
capital budgeting technique:	a criterion for project selection, particularly in the private sector. This approach is based on calculation of rates-of-return on investment in R&D.
capital outlay:	one-time expenditure of a fairly significant sum of money.
chain of command:	the relative vertical depth in an organization chart reflects the number of discrete levels of authority.
contingency planning:	the process of developing secondary plans for R&D tasks, activities, administration, etc., which will be implemented if the primary plans turn out to be unrealistic.
controlling:	the process of making adjustments which correct for the deviations from planned progress.
control points:	those points-in-time, in the course of an R&D project, when some technical or administrative deliverable may be used as an indicator of the overall technical, cost and/or schedule performance of the project.
cost benefit analysis:	a systematic comparison of the cost of carrying out an R&D activity, and the value of that activity—quantified as much as possible.
cost centres:	a concept for financial management, which identifies the smallest particular organizational units or research activities to which costs may be held accountable in an RDI.
cost prediction formula:	a quantitative technique for predicting the ultimate costs of an R&D project, or components of a project.

cost standards:	uniform and relatively stable guidelines for planning the costs of resources which are used frequently by the RDI.
CPM:	Critical Path Method refers to a quantitative technique which, when applied to network planning, is helpful in calculating the minimum time and sequence of tasks needed to complete an R&D project.
critical path:	that path along a network plan which requires the greatest time for completion.
deliverables:	general term to refer to the planned administrative or technical results of an R&D task, project or programme.
deliverables chart:	an adaptation of the bar chart, the deliverables chart includes the identification of key results of technical work, or completion of administrative tasks associated with the project, like periodic activity and status reports to RDI management.
development work:	uses the results of applied research to create the form and substance of a new product, or process, or improve present ones.
deviation:	the difference between anticipated (planned) and actual results.
directing:	coordinating the application and expenditure of all resources required to complete an R&D task, project or programme—including labour, supplies, facilities and money.
direct costs:	those R&D project costs which are directly traceable to the project—such as the cost of materials or labour.
down-time:	time gone by when no work is done on the R&D project.
discrete results:	characteristic of an R&D project component which makes it easy to isolate technical outcomes.

financially discrete:	characteristic of an R&D project component which makes it easy to calculate costs.
fiscal year:	that twelve-month period which the government has determined shall be the basis for budgeting all government activities. It may, or may not coincide with the January–December calendar year. It may, or may not coincide with the fiscal year of any other organization, e.g., an R&D client in the private sector.
fringe benefits:	personal compensation for work done, usually given in the form of insurance, paid leave, housing, transport or some other perquisite.
Gantt chart:	simply another name for a “bar chart”; sometimes called this because it was refined as an instrument for planning by a man named Gantt.
goals:	general statements of the desired outcomes of R&D.
indirect costs:	sometimes these are called overhead; they comprise all costs of R&D which are allocable to the general R&D function, but not to any particular project.
level-of-effort:	a general term for the amount of work required to accomplish an R&D task, project or programme. It is usually equated with the amount of money required, labour needs, materials or other resources required to do the job.
line functions:	a relationship between two or more units in an organization, which is based principally on differences of authority.
monitoring:	the process of observing project progress and resource utilization, and anticipating deviations from planned expectations.
networks:	two-dimensional schema for depicting the principal technical elements of any R&D project, and their technical and scheduling relationships (see: ABC, CPM and PERT).

nodes:	points on a chart where the two dimensions of a matrix organization intersect.
objectives:	very specific, highly technical, and frequently quantitative statements of the expected results of R&D project tasks.
operating budget:	the plan for expenditure of money for all costs associated with actually running an R&D programme. It is based on the final appropriation of funds by the government.
operations:	the actual conduct of the research and development activity in an RDI; a term used to distinguish the act of conducting R&D from that of planning or policy.
organization chart:	a two-dimensional, rectilinear schematic of the roles, responsibilities and functional relationships among units in an RDI.
organizing:	using the characteristics of structure to establish technical and authority relationships among units of an RDI.
overhead:	the collection of indirect costs of R&D for an RDI.
parameter:	a variable; usually a monitored budgetary threshold which triggers control decisions.
peer review:	usually a technical review of R&D work, conducted by people who are of similar technical calibre and level of authority as the person responsible for the work.
PERT:	<i>Program Evaluation and Review Technique</i> is the name given to a network approach to planning, monitoring, controlling and evaluation. Designed for particularly complex tasks, and detailed planning, it can be applied in a highly quantitative format. Otherwise it consists of a two-dimensional schematic of the relationships among tasks in an R&D project.
planning:	setting appropriate objectives for R&D work; then selecting courses of action which are most likely to result in effective

fulfillment of them. (See: strategic, and project planning.)

policy:	principles of management established by the leadership of an RDI, to guide research managers at all levels of the organization.
portfolio:	a general term which refers to the collection of R&D projects selected to fulfill RDI goals for national development.
PPBS:	<i>Programme Planning and Budgeting System</i> is a very comprehensive budgeting process which requires considerable effort to develop refined goals, objectives, tasks, and costs per each, for all activities in the RDI. The process is far more accurate than most budgeting techniques—but its level-of-effort precludes the wisdom of doing it annually.
programme:	a group of R&D projects which are related either by a common technology, a common sponsoring organization, or a common executing unit of the RDI.
proposal:	a statement of the objectives, methods, resources and management plan for an R&D project.
project:	a discrete collection of R&D tasks which are required to fulfill a specific set of related R&D goals, and/or to resolve a specific development problem.
project planning:	focuses on R&D projects; generates specific project objectives, tasks, resource requirements and schedules.
quarterly:	budgetary term referring to a three-month term for planning; one quarter of a year.
R&D:	<i>Research and Development</i> is a phrase which encompasses the wide range of technical activities required to derive special knowledge and process which will help resolve the nation's development problems.

R&D management:	the efficient and effective marshalling, allocation and control of human, material and financial resources in a manner which perpetuates a creative environment in which research and development activities may be used to focus technology on priority national development problems.
rate of completion:	literally, how fast an R&D project is completed; quantitatively the slope of a line which represents the total proportion of technical work done (or planned to be done) for each control point (e.g., monthly, quarterly, annually, etc.).
rate of expenditure:	literally how fast money is spent over the life of an R&D project; quantitatively it is represented by the slope of a line which represents the total proportion of available funds spent (or planned to be spent) for each control period (e.g., monthly).
RDI:	Research and Development Institute is a general term we use in this material to refer to any organization which is primarily responsible for the application of R&D methodologies for the solution of social and economic development problems.
researchers:	those research managers who are primarily responsible for the output of the RDI, through: (1) bringing specialized technology to bear on the resolution of national development problems; (2) proposing, conducting and reporting the results of research projects; and, (3) furthering the technical productivity and capability of the RDI.
research management:	the efficient and effective marshalling, allocation and control of human, material and financial resources in a manner which perpetuates a creative environment in which research and development activities may be used to focus on priority national development problems.
scoring and ranking techniques:	any of a number of approaches to comparing R&D proposals in a pseudo-quantitative basis, prior to project selection. First, criteria for project selection are determined, then all proffered projects are rated on each criterion. They are then arrayed in order of their overall ranking and selection is based on the resultant ranking.

slack time:	period during the conduct of any R&D project during which no work can be done for reasons beyond the control of project managers.
span of control:	the relative extent of control exerted by a RDI leader as reflected by the horizontal spread of subordinate units or individuals (in an organization chart).
staff functions:	a relationship between two or more units of an organization, which is based on no differences in authority.
strategic managers:	those research managers who are primarily responsible for directing the whole R&D activity, through: (1) ensuring that the R&D activity coincides with national development priorities; (2) garnering the human, material and financial resources needed to carry out the work of the RDI; and, (3) establishing the fundamental rules and standards by which all RDI activities will be managed.
strategic planning:	focuses on RDI goals, scope of R&D activities, and RDI resources; establishes the relationship between RDI mission and national development goals; frequently serves as a basis for RDI policy development.
support staff:	those research managers who are primarily responsible for supporting strategic and research activities by: (1) collecting, combining, analysing and interpreting information on all institute operations; (2) converting institute policies to management systems; and (3) facilitating the relationship between institute policy makers and researchers.
task:	one component of an R&D project, which may be differentiated from others by the distinct characteristics of its technical results, costs or scheduling.
task list:	a fundamental basis for planning R&D projects—the task list is simply a list of those technical components of a project which may be isolated in discrete categories of technical activity, cost, or scheduling.

technically discrete:	characteristics of an R&D project component which involves a distinct and separate methodology, which can easily be distinguished from the technical work on other components.
technology:	the science of controlling forces, both natural and social, to produce desired effects.
technology assessment:	a technique for evaluating the consequences of applying technology to the problems of society.
temporally discrete:	characteristic of an R&D project component which makes it easy to isolate from others in time and sequence.
tolerances:	acceptable ("tolerable") deviations in some R&D project performance parameter.
unit costs:	a standard for costs per piece, used for budgeting resources which have fairly stable costs, and which are used frequently by the RDI.
variance:	the amount actual time, real costs or final R&D results deviate from the values anticipated in a plan.
work breakdown schedule:	a list of R&D project tasks accompanied with task durations and dependent, or precursor tasks.
zero-based budgeting:	an approach to annual budgeting exercises in which each programme to be considered is re-examined on the basis of its present merits—rather than on the basis of past funding decisions.

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Highly quantitative model for relating behaviour of earnings and stock prices to increased R&D spending.

Executive Director, Permanent Committee (UNIDO Industrial Development Board). **Joint UNDP/UNIDO Evaluation of Industrial Research and Service Institutes.** Vienna: UNIDO; September 25, 1979; ID/B/C.3/86.

Good overview of IRSIs, though slightly dated. Evaluation of the role of IRSIs in national development.

Food and Agriculture Organization of the United Nations. **Improving the Organization and Administration of Agricultural Services to Small Farmers in Africa;** Report of a consultation held in Nairobi: November 29–December 3, 1982.

Foundation for International Training. **Management of Research and Development Institutes: An Asian Perspective;** Don Mills, Ontario: 1983.

Chapter 4 contains a good piece on financial planning and control. Whole book overviews, through contributed papers, the Asian RDI management experience.

Foster, Richard N. "Estimating Research Payoff by Internal Rate of Return Method. **Research Management;** November, 1971: 27–43.

Highly quantitative presentation of internal rate of return method for estimating payoff from R&D; requires knowledge of algebra and calculus.

Francis, Philip H. **Principles of R&D Management.** New York, NY: AMACOM; 1977; ISBN 0-8144-5451-8.

Freeman, J. R. "A Survey of the Current Status of Accounting in the Control of R&D". **IRE Transactions on Engineering Management;** December, 1962: 179–181.

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Gambino, Anthony J. and Gartenberg, Moris. "Costing and Reporting R&D Operations". **Research Management;** July, 1979: 15–18.

This article tells how to allocate and control R&D expenses, and also describes performance and financial reports in common use today.

Gambs, Gerard C., Assistant to the Vice President, Research and Development (Consolidated Coal Company). **Representative Costs of Doing Research and Development.** In: **Industrial Research Institute—Young Presidents' Organization.** Symposium on Industrial Research; March 2–3, 1959: 33–43.

Report on collection of surveys on the nature, scope and costs of R&D in the U.S.

- Gellein, Oscar S. and Newman, Maurice S. "Some Basic Accounting Principles for R&D". **Research Management**; July, 1973: 20-23.

Geared very closely to R&D accounting practices in for-profit manufacturing operations. Answers: what portion of the R&D costs should be deferred? How should deferred costs be amortized? What information should be given in financial statements?

- Gerstenfeld, Arthur. **Effective Management of Research and Development**. Reading, Massachusetts: Addison-Wesley Publishing Company; 1970; ISBN 73-109511.

Interesting and useful as general presentation of R&D management approaches; but too closely tied to U. S. R&D manufacturing interests to be highly significant for R&D in developing economies. Reviews management approaches actually applied in U. S. manufacturing firms; through surveys and interviews with firms.

- Gibson, J. E. "Planning and Budgeting: Keys to Successful R&D". **Machine Design**; July 20, 1978: 58-63.

Success of R&D depends on adequate long-range funding and rigorous project budgeting.

- Gold, Bela. **Research, Technological Change, and Economic Analysis**. Lexington, Massachusetts: Lexington Books; 1977; ISBN 0-669-01286-6.

Many contributors of original pieces; good chapter (no. 6) on reported economic effects of technological change.

- Gomez, Manel I., Professor, Department of Biochemistry, Food Science Programme (University of Zimbabwe). **Development of Human Resources** (paper). At: FAO, Expert Consultation. Strategies for Research Management Training in Africa; December 12-16, 1983; Addis Ababa. Harare, Zimbabwe: University of Zimbabwe; December, 1983.

Does good job of describing problems of researchers turned into managers.

- Hainer, Raymond M. (and others). **Uncertainty in Research, Management, and New Product Development**. Cambridge, Massachusetts: Reinhold Publishing Corporation; 1967.

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- Hanson, W. T., Jr. and Nason, H. K. "Funding and Budgeting R&D Equipment and Facilities". **Research Management**; September, 1980: 25-28.

Interviews with research executives in twenty large companies provided information on current policies and practices for budgeting R&D equipment.

Harvey, Robert E. "Putting a Price Tag on Research". **Iron Age**; October 6, 1980: 71-75.

Surveys U.S. R&D expenditures as a percentage of GNP.

Hawthorne, Edward P. **The Management of Technology**. Maidenhead, England: McGraw-Hill Book Company (UK); 1978; ISBN 0-07-084512-3.

Provides good background in general technology development; background for a more detailed study of R&D in developing economies. Discusses the role of technology in economies, and the role of people and organizations in furthering technologies.

Heyel, Carl. **Handbook of Industrial Research Management**. New York, NY: Reinhold Publishing Corporation; 1959.

Dated but basic R&D management overview; helpful for developing economies because it traces development of management ideas when U.S. R&D sector was just beginning to thrive.

Industrial Information Section (UNIDO Technology Programme). **Directory of Industrial and Technological Research Institutes in Africa**. Vienna: United Nations Industrial Development Organization; March 23, 1982. (UNIDO/IS.299).

Good source for biodata on RDIs in Africa. Lists names, addresses, personnel, technical areas of RDIs.

Johnston, Ron and Gummett, Philip. **Directing Technology: Policies for Promotion and Control**. New York, NY: St. Martin's Press; 1979; ISBN 0-312-21218-6.

Edited study, contributed by many original authors; second part (100 pps.) good underpinning for consideration of relationship between policy and control of R&D.

Kamenetzky, Mario, Director (Science and Technology Unit, Projects Advisory Staff, The World Bank). **Choice and Design of Technologies for Investment Projects** (paper). Washington, D. C.: The World Bank; August, 1982.

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Kipp, E. M. "How to Construct an Effective Corporate R&D Budget". **Research Management**; May, 1978: 14-17.

Good process orientation to planning in an R&D organization. An opportunity for R&D staff to participate in the formulation of R&D programmes and plans can have a number of important benefits for the RDI.

Kolding, K. E., Resident Representative (Kenya), Food and Agriculture Organization of the United Nations. **Improving the Organisation and Administration of Agricultural Services for Small Farmers in Africa (report of proceedings)**. Regional Expert Consultation. Rome: Human Resources, Institutions and Agrarian Reform Division, FAO; 1982.

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Kornfeld, Jack P. "Cost-Effectiveness as a Method of Evaluating Design Changes". **IRE Transactions on Engineering Management**; March, 1962: 15-23.

A procedure is outlined for utilizing cost-effectiveness as a measure of the economic feasibility of making design changes.

Lambert, Vernon L. and Sackett, Hubert F. "Research and Development Cost Estimation". **IRE Transactions on Engineering Management**; March, 1959: 8-12.

Four companies engaged in R&D were interviewed relative to their method of cost prediction.

Libik, George. "The Economic Assessment of Research and Development". **Management Science**; September, 1969; 16 (1): 33-66.

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Good basics on role of R&D managers in budgeting for R&D, and relationship of budgeting exercises to R&D planning. Overview of Owens Corning, Inc., approach to R&D budgeting and planning.

Ludington, Varnum D. "Survey of Indirect Costs in Industrial R&D". **Research Management**; 1970; 13 (2): 169-176.

A survey of RDIs reveals indirect cost accounting practices; good only for identifying indirect cost categories.

Lynch, Charles J., Senior Editor. **Managing Advancing Technology: Strategies and Tactics of Product Innovation**. Staff of Innovation Magazine. Innovation. New York, NY: American Management Association, Inc.; 1972; Vol. 1; ISBN 0-8144-5283-3.

One of the early contributors to theories of innovation; based on experiences in industrialized economies.

Marcovitch, Jacques. *Administracao em Ciencia e Tecnologia*. Sao Paulo, Brazil: Editora Edgard Blucher Ltda.; 1983.

Good overview of science and technology as related to development; contributed chapters; in Portuguese with English summary paragraphs.

Maybury, Robert, Associate, Project Advisory Staff, Science and Technology Unit (The World Bank). *Financing of Research, Invention and Innovation* (paper). Washington, D. C.: The World Bank; July, 1983.

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Mook, Byron, Senior Research Officer (ISNAR). *Training for Agricultural Research Management: The ISNAR Approach* (conference paper). At: FAO, Expert Consultation. Strategies for Research Management Training in Africa; December 12–16, 1983; Addis Ababa. Rome: Food and Agriculture Organization of the United Nations; December, 1983.

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Muhammed, Amir, Consultant (FAO). *Research Management Training Needs in Developing Countries* (paper). Read at: FAO, Expert Consultation. Strategies for Research Management Training in Africa; December 12–16, 1983; Addis Ababa, Ethiopia. Rome: November, 1983; Food and Agriculture Organization of the United Nations; W/M 6243.

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Newman, Maurice S. "Accounting for Research and Development Expenditures". *Research Management*; 1965; 8 (4): 241–260.

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Peters, Thomas J. and Waterman, Robert H., Jr. In: **Search of Excellence: Lessons from America's Best-Run Companies**. New York, NY: Warner Books; 1982; ISBN 0-446-37844-5.

Good source for overriding management principles in any organization. In depth analysis of what makes the most successful companies run and function smoothly; focuses on management methods and styles.

Pliner, Roberta Lee, Editorial Associate. "Creating An Action Team in R&D". In: Innovation Books, Editors. **Managing Advancing Technology**. New York, NY: American Management Association; 1972; Vol. 2; ISBN 0-8144-5284-1.

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Pons, Alain. **Research Management**. Paris, France: Organization for Economic Cooperation and Development; 1965.

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Rao, K. N. and Weiss, Charles. **Government Promotion of Industrial Innovation**. Washington, D. C.: World Bank.

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Reeves, E. D. "Development of the Research Budget". **Research Management**: 133-142.

Overviews the general importance of the research budget.

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Good piece on profit centre management of R&D; useful background on relationship of organization to R&D control.

Rosen, E. M. and Souder, W. E. "A Method for Allocating R&D Expenditures". **IEEE Transactions on Engineering Management**; September, 1965; EM-12 (3): 87-93.

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Rosenau, Milton D., Jr. "Problems with Optimizing Research Spending". **Research Management**; November, 1980: 7.

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Sharif, M. Nawaz, Professor of Systems Engineering, Asian Institute of Technology; Bangkok, Thailand. "Role of R&D Institutes: An Overview". In: **Management of Research and Development Institutes: An Asian Perspective**; Foundation for International Training; Don Mills, Ontario: 1983.

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Souder, William E. "Budgeting for R&D: A Case for Management Science Methods". **Business Horizons**; June, 1970: 31-38.

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Snow, Sir Charles P. **The Two Cultures and the Scientific Revolution**. New York: Cambridge University Press: 1961.

Published in 1961 from 1959 lecture. Sir Charles comments on fundamental cultural rift between scientists and non-scientists; he places a challenge to overcome differences. Fascinating theme when considered in light of Third World RDIs and role of science and technology in development.

Suran, Jerome J. "R&D Management: An Operational View". **IEEE Transactions on Engineering Management**; March, 1965; EM-12 (1): 14-22.

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United Nations. Critical Elements in Managing Science and Technology for Development. **Proceedings of the Panels of Specialists of the UN Advisory Committee on Science and Technology for Development** held at Kuwait (8–11 January) and Tunis (6–9 April 1983).

Good critical overview of industrial research and service institutes around the world.

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Wad, Atul, Associate Professor (Centre for the Interdisciplinary Study of Science and Technology, Northwestern University). **The Management of Research and Development in Developing Countries: Discussion Notes on the Management of Scientists and Engineers and the Marketing of R&D** (report). For: Training Seminar. Science and Technology Policy. Washington, D. C.: The World Bank; May 19, 1982.

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Walker, J. D. and Houry, E. "A comparison of Actual and Allocated Costs for Work Accomplished Using NASA's PERT". **IEEE Transactions on Engineering Management**; September, 1965; EM-12 (3): 93–102.

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White, Percival A. F. **Effective Management of Research and Development**. New York, NY: John Wiley & Sons; 1975; ISBN 0-470-94063-8.

Based on British experience with R&D, it has some parallels in developing economies; good chapter on controlling R&D.

Wilson, T. L. "Budget and Cost Control in Research and Development". **Research Management**; 1959; 95–105.

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Working Group, Editor (European Research Management Association). **Research Laboratories: Budgeting and Control of Expenditures**; Paris: 1970; 2 (4): 11–12.

Good summary of useful RDI budgeting policies.

Zimbabwe, Government of the Republic of. **Transitional National Development Plan: 1982–1985.** Harare, Zimbabwe: Government Printing Office; November 1982 (Vol. 1), May 1983 (Vol. 2).

Details GOZ's plans for economic and social development for the three-year period; two volumes; limited mention of S&T and R&D; by sector; useful to consider relationship of both to national development goals.